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ABSTRACT

This document is a listing and review of the research pertaining to secondary school mathematics published in the United States over the past several years. The bibliography, in two appendices, lists 780 research reports and 770 dissertations dealing with secondary school mathematics published between 1930 and 1970. Each citation is followed by one or more category codes for the educational area and mathematical topic researched in the document. A complete listing of the coding scheme is included. The body of the paper is a review of this research listing. The majority of studies cited were done between 1960 and 1970; older studies are cited primarily for historical perspective. The review is organized around the themes of planning for instruction, attitudes and related factors, content, individualizing instruction, instructional materials and media, and teacher education. Additional appendices list the frequency of reports and dissertations by year and topic. (Editor/JM)

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MATHEMATICS EDUCATION REPORTS

A REVIEW OF RESEARCH ON SECONDARY SCHOOL MATHEMATICS

by Marilyn N. Suydam

ERIC Information Analysis Center for
Science, Mathematics and Environmental Education
1460 West Lane Avenue
Columbus, Ohio 43210

March, 1972

Mathematics Education Reports

Mathematics Education Reports are being developed to disseminate information concerning mathematics education documents analyzed at the ERIC Information Analysis Center for Science, Mathematics, and Environmental Education. These reports fall into three broad categories. Research reviews summarize and analyze recent research in specific areas of mathematics education. Resource guides identify and analyze materials and references for use by mathematics teachers at all levels. Special bibliographies announce the availability of documents and review the literature in selected interest areas of mathematics education. Reports in each of these categories may also be targeted for specific subpopulations of the mathematics education community. Priorities for the development of future Mathematics Education Reports are established by the advisory board of the Center, in cooperation with the National Council of Teachers of Mathematics, the Special Interest Group for Research in Mathematics Education, the Conference Board of the Mathematical Sciences, and other professional groups in mathematics education. Individual comments on past Reports and suggestions for future Reports are always welcomed by the editor.

This paper fills a long-standing need for a listing and review of the research pertaining to secondary school mathematics published in the United States over the past several years. The bibliography (Appendices A and B) list 780 research reports and 770 dissertations dealing with secondary school mathematics and published between 1930 and 1970. Each citation is followed by one or more category codes for the educational area and mathematical topic researched in the document. A complete listing of the educational area and mathematical topic coding scheme is found on the next four pages.

The body of the paper is a review of this research listing. The majority of studies cited in this review were done between 1960 and 1970. Older studies are cited primarily for historical perspective. The review is organized around the themes: planning for instruction, attitudes and related factors, content, individualizing instruction, instructional materials and media, and teacher education.

The ERIC Information Analysis Center for Science, Mathematics, and Environmental Education is pleased to make this review and bibliography available as a Mathematics Education Report.

Jon L. Higgins
Editor

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CATEGORIES AND CODING FOR MATHEMATICAL TOPIC

a. Planning for Instruction

1. Historical developments
2. Nature, values, and uses of mathematics
3. Organizational patterns (departmentalized; multi-graded; self-contained; non-graded; team teaching)
4. Teaching approaches (modern, traditional; expository, discovery; rote, meaning; incidental, systematic; activity, mathematics laboratory; aptitude-treatment interaction)
5. Instructional procedures
    - a. Drill and practice
    - b. Problem solving
    - c. Estimation
    - d. Mental computation
    - e. Homework and supervised study
    - f. Review
    - g. Checking
    - h. Writing and reading numerals
    - i. Specification of objectives
6. Attitude, self-concept, and climate
7. International comparisons

b. Content: Sequencing and Structuring

1. Pre-first grade concepts
2. Readiness
3. Content organization and inclusion
4. Quantitative understanding
5. Grade placement
6. Time allotment

c. Content: Methods of Instruction

1. Counting
2. Number properties and relations
3. Whole numbers
    - a. Addition
    - b. Subtraction
    - c. Multiplication
    - d. Division
4. Fractions
    - a. Addition
    - b. Subtraction
    - c. Multiplication
    - d. Division
5. Decimals
6. Percentage
7. Ratio and proportion

8. Measurement
9. Negative numbers (integers)
10. Algebra in elementary school
11. Geometry in elementary school
12. Sets
13. Logic and proofs
14. The decimal numberation systems
15. Other numeration systems
16. Probability and statistics
17. Functions; graphing
18. (Unassigned)
19. (Unassigned)
20. Basic arithmetic procedures in secondary school
21. General mathematics course
22. Algebra course
23. Geometry course
24. Trigonometry course
25. Calculus course
26. Other courses
27. (Unassigned)
28. (Unassigned)
29. (Unassigned)
30. Other topics

d. Materials

1. Textbooks
2. Workbooks, other printed materials
3. Manipulative devices, games
4. Audio-visual devices
5. Programmed instruction
6. Computer-aided instruction
    a. Tutorial
    b. Non-tutorial
7. Readability and vocabulary
8. Quantitative concepts in other curricular areas
9. Developmental projects (SMSG, etc.)

e. Individual Differences

1. Diagnosis
    a. Error analysis
    b. Diagnostic procedures
2. Remediation
    a. Low achiever, underachiever
    b. Slow learner
    c. Mentally retarded
    d. Tutoring
3. Enrichment
    a. Overachiever
    b. Acceleration

  - 4. Grouping procedures (ability, homogeneous, individualized, flexible)
  - 5. Physical psychological, and/or social characteristics (anxiety)
  - 6. Sex differences
  - 7. Socioeconomic differences

f. Evaluating Progress

  - 1. Testing
    - a. Analysis and validation of tests
    - b. Status testing
  - 2. Achievement evaluation
    - a. Related to age
    - b. Related to intelligence
    - c. Related to prediction
  - 3. Effect of parental knowledge
  - 4. Effect of teacher background and characteristics

g. Learning Theory

  - 1. Transfer
  - 2. Retention
  - 3. Generalization
  - 4. Thought processes (categorization, organization, creative and critical thinking, concept formation)
  - 5. Motivation
  - 6. Reinforcement
    - a. Knowledge of results
    - b. Other procedures
  - 7. Piagetian concepts
    - a. Conservation
      - 1) Development
      - 2) Training
      - 3) Relation to achievement
    - b. Transitivity
    - c. Classification and seriation
    - d. Other

m. Mathematics

  - 1. Philosophy and theory
  - 2. Persons and texts
  - 3. Topics (content)
  - 4. Other

p. Other Post-Secondary Education

  - 1. Mathematical background
  - 2. College mathematics instruction
  - 3. Vocational training

r. References

  1. Bibliographical lists
  2. Summaries and reviews

t. Teacher Education

  1. Pre-service
     a. Competency levels
     b. Preparation procedures
     c. Attitudes
     d. Characteristics
  2. In-service
     a. Competency levels
     b. In-service procedures
     c. Attitudes
     d. Characteristics

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A REVIEW OF RESEARCH
ON SECONDARY SCHOOL MATHEMATICS

Marilyn N. Suydam

This started out to be a comprehensive review of research on secondary school mathematics -- but it took a practical turn.

- It consists of questions for which research could provide an answer . . .
- And it consists of answers, from research which did provide some answer . . .

Only certain studies were included . . .

- Practically all were done between 1960 and 1970. Only occasionally are older studies cited, primarily to give some degree of historical perspective.
- Practically all could be considered as being of average or better quality as research. The findings of poor studies are not included. This doesn't mean that the studies which are cited have no flaws -- alas, the researcher working in the real school environment almost invariably runs into some problems (just as other teachers do . . .). Such problems have occasionally been pointed out. The focus is on the findings which seem valid -- from the data and for the teacher . . .

The studies cited in this review are a subset of another set . . .

- 780 research reports, and
- 770 dissertations.

That's 1,550 documents on secondary school mathematics education -- research of various types, conducted with and/or about students in grades 7 through 12.[1] You will find them all listed in Appendices A and B.

- Appendix A lists the research reports. These were located in 59 journals published in the United States and/or included in the Educational Resources Information Center (ERIC) files. Would you like to know the sources and the number found in each? That information is noted in Appendix C-1.
- Appendix B lists the dissertations. These were located primarily in Dissertation Abstracts, which has recently been renamed Dissertation Abstracts International. Some people are curious about the universities at which these dissertations were done. To save them counting time, that information is listed in Appendix C-2.

All 1,550 documents were published between 1930 and 1970. The table in Appendix D-1 indicates how many research reports were done in each decade. Appendix D-2 presents this information for the dissertations.

The research studies were done on a variety of topics, which are reflected by the questions which are asked and answered. In case you are interested in seeing the total number of studies categorized by each topic, that information is included in Appendix E-1 for research reports and Appendix E-2 for dissertations.

As you read the questions and answers, it may help you to know that they've been organized around several themes:

1. Planning for instruction
2. Attitudes and related factors
3. Content: what, when, and how
4. Individualizing instruction
5. Instructional materials and media
6. Teacher education

If you would like a list of all of the questions, see Appendix F.

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[1] This compilation, developed under a grant from the U.S. Office of Education, National Center for Educational Research and Development, was entitled "Annotated Compilation of Research on Secondary School Mathematics, 1930-1970," Grant No. OEG-3-71-0085, Final Report, February 1972. The 1,550 documents are each categorized on ten variables, and annotated. Experimental research reports are also evaluated.

Some general comments . . .

What is the purpose, the goal, the hope of those doing research on school mathematics? The answers to four general questions are being sought:

- What and how have we taught in the past?
- What and how are we teaching now?
- What and how should we teach now?
- What and how might we teach in the future?

Obviously, the focus is on *what* and *how*: content and methods. The need to develop a theory of instruction is a professed concern of many researchers today, but it is rarely reflected by the depth of the studies on secondary school mathematics.

It's tempting to say, "The picture of research on secondary school mathematics is incomplete, there are gaps, because the document base is incomplete."

That only accounts for some of the gaps.

What accounts for others? Two of the major reasons are:

- Common sense: a topic isn't subjected to research design because the outcomes of that research are obvious. Long years of a type of "action research", i.e., use, have indicated how good certain procedures are.
- Transfer: the results of studies in other subject areas (such as science), other disciplines (such as psychology), other levels (such as the elementary school), have been recognized for their significance to secondary school mathematics education.

Research on secondary school mathematics has rarely been surprising. Willoughby says it another way in the *Encyclopedia of Educational Research* (1969): "In spite of all this activity, the results of the research are somewhat disappointing." Yet Romberg (1969) sounds a positive note: "Current research in mathematics education can be characterized as large in quantity, poor but improving in quality, and diverse."

And so . . .

There are some answers . . . to some questions . . .

1. PLANNING FOR INSTRUCTION

How do class organization patterns affect achievement?

As is generally true about the research on this topic -- in elementary school mathematics and in other areas of the curriculum -- the findings are equivocal. The studies are frequently of the action-research type, which implies less-firm control of variables; when firmer controls are attempted, the problem of extraneous variables is still present. This causes an analysis problem -- for it remains true that any organizational pattern will be affected by a multitude of variables. And it seems evident that one generalization can be made: any organizational pattern can be effective, can result in better achievement, depending on the variables involved. Chief among these is the teacher factor: if the teachers are committed to a particular pattern, they can make it work. Conversely, some teachers can make any pattern work.

Thus it seems clear that there is no one organizational pattern which is best.

Consider some evidence on team teaching. Baley and Benesch (1969) evaluated an action-research project and reported that multilevel team teaching with individualized instruction produced higher achievement in computational skills than did traditional methods. Paige (D 1966; 1967)[2] found no significant differences[3] in mathematical achievement or retention or relearning ability for students taught by team teaching or by a single teacher.

The evidence on continuous progress and non-graded plans is similarly non-decisive. Kellet (1966) reported that self-study materials given to sixth and seventh graders to help them "bridge the gap" between the two grades, resulted in no significant change in either achievement or attitude. Steere (1967) found that tenth graders in graded schools had gained significantly more in mathematics reasoning than had students in non-graded schools.

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[2] The "D" in front of the year indicates that the reference is a dissertation, and is listed in Appendix B. When only a year is given, the reference is a research report, listed in Appendix A.

[3] "Significance" refers to statistical significance. By this is meant that there is a specified likelihood that such differences would not have occurred by chance. Usually, the level of significance is set at .05, or .01, or .001 -- thus the results might occur by chance only 5 times in 100, or only 1 time in 100, or only 1 time in 1000. "No significant differences" means that a specified level of significance was not reached -- thus the results could occur more frequently by chance. Researchers set a level which seems appropriate to them in terms of the content and design of their study.

Many studies have compared self-contained classrooms with various types of grouping plans. Heger (D 1965) reported that seventh graders taught in self-contained classrooms scored higher on problem-solving and concepts tests than a "core" group, while Morrison (D 1967) found that those in self-contained classes scored higher on reasoning and computation tests than those in departmentalized classes. Campbell (D 1965) reported that there was no significant difference in achievement between groups in grade 7 having whole-class instruction or grouping within the class.

Willcutt (1969a) and Bachman (D 1969; 1970) both found that the achievement of seventh graders in self-contained classes was not significantly different from that in ability-grouped classes. Willcutt reported that those in ability-grouped classes had a more positive attitude, while Bachman indicated a positive relationship between self-concept and achievement.

What is the role of inductive and deductive strategies in the teaching-learning process?

There has been much concern with the relative effectiveness of inductive and deductive strategies. There is, however, much confusion resulting from use of terms: "discovery", or "guided discovery", and "expository" are frequently used in place of "inductive" and "deductive". Rarely are the materials which are used carefully described, and thus the terms may mean different things in different studies.

The results of the studies are equivocal . . . or, as Tanner (1969) noted in a review of research on the topic, "they defy synthesis".

Programmed instruction has been used extensively in studies on this topic, because of the control which can be maintained on the teaching strategy. Belcastro (D 1962; 1966a; 1966b) and Hountras and Belcastro (1963) reported that a program in which algebra was presented to eighth graders using a verbal deductive technique resulted in higher achievement at each intelligence level than non-verbal deductive or verbal and non-verbal inductive programs. While variables were comparatively carefully controlled, and the number of students was large, the study was only a three-day one: the effect of such instruction over a longer time-span is well worth considering.

From a one-day study, with retention measured after three days, two weeks, and six weeks, Kersh (1962) concluded that the guided discovery procedure "motivated the student to practice more and thus to remember and transfer more than he might" if he were taught by a directed procedure. The rote-learning group of tenth graders was, however, consistently superior.

Lackner (1968; D 1969) reported that a concrete inductive method (involving an example-to-rule procedure) resulted in better achievement with programmed calculus materials used for one semester with students in grades 11 and 12 than an abstract deductive (rule-to-example) method.

In other studies, no differences were found between groups taught by the varying strategies. Meconi (D 1967; 1967) reported that high-ability pupils in grades 8 and 9 learned and retained effectively the necessary concepts for problem-solving performance and retention regardless of whether they used rule-and-example, guided discovery, or rule-only programs. No significant differences were found between groups using a program on the field axioms with a discovery strategy in which the student received cues if he needed them and an expository strategy in which he was required to answer a set of questions (Patterson, D 1970).

On the other hand, Eldredge (D 1966) found that a guided discovery program was more effective than an expository program, concluding that how materials are sequenced has an effect on learning.

Eighth graders who used a discovery program on exponents with no verbalization of rules scored significantly higher on tests of understanding, transfer and retention than those using an expository program or a discovery program in which they were asked to state rules (Neuhouser, D 1965).

Other researchers have recognized that we need to know the effect of inductive and deductive approaches with modes of classroom instruction other than programmed materials.

Michael (1949) reported that deductive procedures used in teaching a 45-day unit on integers in grade 9 produced significantly greater gains on a test of generalizations than did inductive procedures, while there were no significant differences on tests of computation and attitude. There was some evidence that those a higher IQ levels achieved more with the deductive procedure.

Kleckner (D 1969) found that non-discovery classes of slow learners in grades 9 and 10 achieved significantly more than classes taught by discovery-type strategies in a mathematics laboratory setting.

Maynard and Strickland (1969; Maynard, D 1970; Strickland, D 1969) found no significant differences for boys in grades 8 and 9 who were taught by a non-verbalized discovery, a guided discovery, or an expository method for six weeks in general mathematics classes.

Werdelin (1968) found that students in grades 6 and 8 taught by instruction on a principle before application to examples tended to learn the mathematical principle best, but those taught by example-only were superior on tests of retention and transfer.

Denmark (D 1965) compared a deductive variation of the algebraic technique (involving use of the solution of an equation); tables were constructed to identify and to organize the parts of the problem, and an equation was derived from the entries in the completed table. In the inductive approach, equations were derived from a pattern which was obtained from attempts to solve the problem by trial and error. He reported that the deductive presentation appeared to be more effective for teaching students to use algebraic techniques to solve verbal problems, while the inductive presentation was more effective when the only consideration was the number of correct problem solutions. It facilitated the development of a variety of techniques, also.

Della-Piana, et al. (1965), in a well-controlled study with students in grades 5, 6, and 9, reported that a guided discovery sequence and method were superior to an expository method in transfer effects and in retention of concepts.

Price (D 1966; 1967) found that tenth graders taught in a general mathematics course for 15 weeks by discovery procedures improved more than a deductively taught group in achievement, reasoning, and attitude. The group using discovery-transfer materials also showed a significant increase in critical-thinking ability.

Volchansky (D 1969) reported that eighth graders taught by a discovery method did significantly better in answering questions of an analytical nature than did those having an expository approach.

Howitz (D 1966) and Brown (D 1970) each found no significant differences in achievement between groups using guided discovery or expository materials on a standardized test, but the guided discovery group scored significantly higher on a non-standardized test. No significant differences in attitude were found.

Amidon (D 1959; Amidon and Flanders, 1961) considered the question of the interaction of student characteristics with teaching method. He identified 140 eighth grade students who tended to comply with authority and to conform to group pressure, referring to them as "dependent-prone". Teacher behavior was considered in terms of the teacher's verbal statements. "Direct" influence consisted of statements, lectures, directions, criticism, and justification of authority. "Indirect" influence consisted of questions, praise, and positive reactions to student ideas and to student emotion.

Students in the indirect teacher influence treatments learned significantly more than did students in the direct teacher influence treatments. Student goal perception seemed to have no effect on achievement.

There were no differences between groups on tests measuring student dependence before and after the treatments. That the experiment lasted only two hours is a weakness: would the same results have been obtained over a longer period of time?

Ashton (D 1962) tested the effectiveness of teaching verbal problems in ninth grade algebra by the heuristic method -- that is, with questions designed to lead students to discovery by means of plausible, inductive reasoning. Five classes were taught to ask key questions such as: "What is the unknown? What are the data? What are the conditions?" Five other classes used a "textbook" method, in which the procedure for solving questions of a particular type was demonstrated for the students, and they were then assigned similar problems for practice. Classes using the heuristic method improved significantly more on a verbal problem solving test than those using the textbook method.

For 18 weeks, Ballew (D 1966) devoted a major portion of the classwork in two algebra classes to the use of discovery exercises; another class was taught by an expository approach. Significant improvement on a test of critical thinking abilities was found in the discovery classes but not in the expository class, though no difference in mathematical achievement scores was found.

Becker (D 1967) tested ninth graders to determine their mathematical and verbal aptitudes. He then paired them according to these aptitudes, and gave them one of two programs. One program gave the learner the correct formula for summing a particular number series in both verbal and symbolic form. The structural relationships between the formula and the series under consideration were explained. In the other program, the learning task was broken into many steps, with examples of the relationship sought. The learner was finally asked to infer the formula for summing the series. No significant interaction effects between either mathematical or verbal aptitude and the type of program were found.

How should time be allocated in mathematics instruction?

Apparently because class schedules are considered "fixed" in most secondary schools, little attention has been given to varying the length of class periods.

Hansen (D 1963) tested the effect of (1) lengthening the class period from 55 minutes to 110 minutes, but meeting on alternate school days only, and (2) using extended class discussions, a mathematics laboratory, library reading and research, class reports, and more instructional aids. He reported that achievement and attitudes were not different from those of students in the daily, 55-minute classes, but results tended to favor the lengthened period.

The amount of time spent within a class on different types of activities would seem to be a viable topic for consideration. Research on this, too, has been limited.

Zahn (D 1966; 1966), in a well-done experiment, had eighth graders spend varying amounts of time for five months on developmental activities and on practice. Developmental activities were those activities of the teacher and the class that were intended to increase understanding of the number system, the fundamental processes or operations, and the general usefulness of number and quantity in everyday experiences. This included teacher and class demonstrations; explanations; group reading; discussions; and the handling, inspecting, and arranging of visual and manipulative materials, such as drawing, construction work, and committee projects. Practice work included activities in which the pupils worked individually with pencil and paper on assigned computation or verbal problems, other exercises prepared by the teacher, or problems taken from the textbook. Students who spent at least half of their time in developmental activities scored higher than those who spent the greater proportion of their time on practice.

Carlow (D 1968) found that practice was effective in increasing retention and transfer, however.

How effective is the specification of objectives?

While a large number of articles have been generated in recent years advocating or criticizing the use of behavioral objectives, little research has been directed toward ascertaining their effect on the teaching and learning of secondary school mathematics.

Proctor (D 1968) developed a learning situation in which (1) learning objectives were operationally clarified for students, (2) feedback was designed to provide teachers and students with knowledge as to the extent to which the student achieved those objectives, and (3) student achievement of the objectives was associated with marks assigned. He reported that, while higher student achievement was associated with the use of operational objectives, classroom activities were not affected by the objectives.

In grade 7, Bierden (D 1969; 1970) studied (1) the classroom use of detailed behavioral objectives related to the content of the course and (2) a form of classroom management using a combination of whole-class instruction and flexible intra-class grouping based on achievement of objectives. Students made significant gains in computational skills, concept knowledge, and attitude, although achievement was not significantly different than for students in groups not using the objectives and grouping plan. Mortlock (D 1970) reported comparable results in a concurrent study with students in grade 11.

Teachers were found to select instructional objectives for low-achieving seventh graders that reflected skills already available to their students, and to gear instruction to skills already achieved by students at the time of their entry into the program (Skager, 1969).

Piatt (D 1970) reported that seventh grade students whose teachers were trained to write behavioral objectives achieved significantly higher scores on tests of computation and concepts than those whose teachers had no such training.

How effective is homework?

The results of studies on homework have not been consistent, as Goldstein (1960) noted in a review of studies with elementary and secondary school students. He concluded that (1) regularly assigned homework favors higher achievement, (2) the cumulative effect of homework is not adequately studied in short-term experiments, and (3) the fact that homework may have adverse psychological effects is unsupported by research.

Seventh and eighth grade classes studied by Brinke (D 1967) did not benefit more from homework than from supervised study. There was some indication that homework was more productive for upper-ability students while supervised study was better for low-ability students. Hudson (D 1965) reported that the amount of homework assigned had no significant relationship to achievement on concepts, but may influence problem-solving scores.

Peterson (D 1970) found that a group receiving exploratory homework assigned for three days prior to the teaching of a topic and a group receiving mathematical puzzles unrelated to the mathematics being taught each achieved better than a group receiving no homework. Those who completed at least 50 per cent of the homework assignments achieved more than the students who did at least half of the puzzles.

No significant differences in test scores or homework grades were found between groups who received only grades or only conferences on homework in elementary algebra (Brown, 1966). Small, Holtan, and Davis (1967), in a study with minimum controls, found that students whose homework was checked and graded differed little in achievement from those whose homework was only spot-checked.

Have there been attempts to analyze the historical development of mathematics in the secondary school curriculum?

Tracing the development of the content and the philosophy of teaching secondary school mathematics was given new impetus by the modern mathematics movement. Yasin (D 1962) traced reform movements since 1900. He noted stages which were defined by (1) concern for the learner, (2) attempts to reduce the number of mathematics courses, (3) inclusion of new topics, (4) weakening of content, and (5) emphasis on structure. Hancock (D 1961) analyzed the instructional aims and recommendations of various groups from 1893 to 1960, noting that they reflect prevailing societal demands. He reported that little attention was given to methods of instruction. In another study of forces that had influenced change, Jamshaid (D 1969) noted that the first reform movement initiated around 1900 was child- and society-centered, while the reform movement which began in 1950 was subject-centered. Fishman (D 1966), studying trends in relation to educational theories and social changes from 1893 to 1964, added that societal influences before 1950 had resulted in a continuous decrease in the percentage of students enrolled in academic mathematics courses and a dilution of the content of courses offered to a majority of students.

Krause (D 1969) identified educators and mathematicians who contributed to the modern mathematics movement, and provided evidence of the evolution of modern mathematics from 1936 to 1957. Oakes (D 1965) reported a gradual evolution in the type and number of objectives for mathematics education from 1920 to 1960. A 1959 report listed only a few well-chosen objectives that dealt with understanding mathematics and its structure, rather than a detailed list that could not be tested.

Some researchers concentrated on specific areas of the curriculum. For instance, geometry has consistently received much attention. Quast (D 1968) analyzed recommendations and practices from 1890 to 1966; Hunte (D 1966) studied the role of demonstrative geometry from 1900 to 1965; and Pruitt (D 1969) analyzed the types of exercises in plane geometry textbooks from 1878 to 1966. Some of the other studies are listed in Table I.

Alspaugh, Kerr, and Reys (1970) identified six trends in curriculum development which are interrelated and have persisted for many years. These trends are associated with the changing objectives and organization of secondary education:

(1) the lowering of grade placement
(2) teaching methods emphasizing understanding
(3) the introduction and deletion of content
(4) the integration of courses (such as algebra and trigonometry, plane and solid geometry)
(5) emphasis on the needs and characteristics of learners
(6) the increasing rate of curriculum change

They also noted the tendency to reorganize courses internally using ideas such as the function concept to emphasize the logical order and structure of mathematics.

TABLE I

OTHER STUDIES ON HISTORICAL DEVELOPMENTS

Author	Year	Topic
Berenson	D 1961	adaptation of mathematics to mass education, 1915-1925
Coleman	D 1942	development of informal geometry
Hawkinson	D 1968	philosophical bases for fundamental concepts
Hinckeley	D 1950	American culture as reflected in mathematics textbooks
Huber	D 1963	developments in junior high school mathematics
Kelley	D 1960	trends, 1955-1960
King	D 1955	algebra textbooks before 1900
Ibrahim	D 1949	implications of philosophies of education
Izzo	D 1957	use of graphs in textbooks
Lichtenberg	D 1967	emergence of structure in algebra, 1830-1900
Nelson	D 1932	materials and methods for algebra, 1829-1929
Pickard	D 1948	evolution of algebra
Ripley	D 1947	factors affecting mathematics education from 1890
Schuler	D 1963	effect of NSF and NDEA funding
Sigurdson	D 1962	development of "unified mathematics", 1890-1930
Wilson, Jack D.	D 1950	algebra trends, 1918-1948
Wilson, John D.	D 1959	geometry content before 1900

What is the evidence on how well students achieve today compared with "the good old days"?

We tend to decry how poorly students of today score on mathematics tests. Evidence exists that this is not a phenomenon of today alone. That's what Lindquist did in 1934, when he reported that only ten of 62 items on the 1933 Iowa test were answered correctly by more than half of the ninth graders tested, and only two items by more than three-fourths of the group.

Or consider Boss in 1940, who found that in grades 3 through 8, median scores of pupils who took a test in 1938 were lower than those who took the same test in 1916.

Some evidence exists on the other side, too.

Sligo (D 1955) noted a significant decline in algebra achievement test scores for students tested in 1954 when compared with students tested in 1934.

Several studies have compared the achievement of students today with that of students in earlier years. Beckmann (1969) found that students at the beginning of grade 9 in 1965 scored as well as those at the end of grade 9 in 1951. Mean score on a 109-item test was 45.7 in 1951, and 54.9 in 1965.

As a consequence of changing emphases in the teaching of algebra over the past 50 years, less attention is given in the instructional program to the development and maintenance of manipulative skills. Despite this de-emphasis, a group of students of elementary algebra in 1966 performed significantly better than did a comparable group of 40 years ago in a test of their skills in solving equations (Leonard, D 1967).

To what extent has modern mathematics been incorporated into the curriculum?

The answer to this question, as most of us know, is, "Quite extensively".

Barto (D 1967) found that 40 per cent of the junior high schools which he surveyed in six midwestern states were using experimental program materials, while most others reported using "modern" textbooks.

Sooy (D 1970) found that most recommended new topics were included in algebra textbooks being used in New Jersey.

Williams (1970a) studied data from college board tests and concluded that (1) some of the recommendations of experimental programs have begun to have wide acceptance, and (2) some topics recommended by the Commission on Mathematics were being integrated into the mathematics program. In a survey of 1,910 students in grade 12, she found that a number of topics considered to exemplify contemporary mathematics were studied by more than 50 per cent (Williams, 1970b).

Is there research which identifies the outcomes of "modern" and "traditional" instruction?

Austin (1969) compared the computational ability of 1965 eighth graders with 1967 tenth graders. He found no significant differences between groups using traditional, transitional, and modern textbooks. A "select" group of tenth graders who had used either a modern or a transitional textbook did "markedly superior" work to those who had used only a traditional textbook. Peterson (D 1967) found that seventh graders using traditional materials achieved significantly lower in mechanical skills than did students using modern or transitional materials, while in application of skills, those using transitional materials achieved the lowest scores.

Moore and Cain (1968) reported that students using a "modern" program had significantly improved scores in logical reasoning, word fluency, and associational fluency.

Davidson (D 1969; Davidson and Gibney, 1969) found that students who had modern mathematics instruction in grade 8 achieved at a significantly higher rate and took more mathematics courses than those who had traditional instruction. Ruddell (1962) found that students in an accelerated class using a program of modern mathematics scored as high or higher than similar children taught a program of traditional mathematics. Payne (1965) summarized several studies and reported that "modern" programs were as effective as "traditional" programs in developing "traditional" mathematics skills. There was evidence that "modern" materials are appropriate for a wide range of student abilities.

However, Ericksen and Ryan (1966) reported few significant differences between students instructed by different modern programs. Initial student ability was the most significant factor involved in achievement and retention. And confusion or interference from a change in method of instruction (i.e., from traditional to modern) was found to exist by Cronin (1967; D 1968). The change interfered with students' recognition of material organized and presented under either the original or the new method.

Simmons (D 1966), in a study with students in grades 5 through 7, found that students receiving instruction under a program of modern mathematics scored higher than those instructed under a traditional program, when achievement was measured by standardized tests designed to determine traditional achievement.

In an 18-week study with eighth graders, Wright (D 1965; 1970) found no significant differences in gains between those using a traditional or either of two modern programs in learning traditional concepts, but those in the modern programs achieved higher scores on a test of modern concepts.

Yasui (D 1968) studied an added dimension: he reported that the achievement of students using modern programs was significantly higher than that of those using traditional programs on test items which both programs had in common.

Thus it seems apparent that the effect of modern or traditional instruction must be considered in relation to the type of test which is used to measure that effect.

To what extent are various courses offered in schools?

In many parts of the country, surveys have been conducted to ascertain the offerings available to mathematics students. For instance, in Iowa, Hawthorne (D 1966) found that trigonometry and algebra II had increased markedly both in offering and enrollment percentages from 1954 to 1964.

Dunson (D 1970) reported that 81 predominantly Negro schools surveyed in Georgia offered general mathematics, algebra I and geometry; however, only large schools offered courses beyond trigonometry. Few had used experimental materials. Crawford (D 1967) found that more than 50 per cent of the ninth graders in Negro schools in Louisiana were enrolled in general mathematics. All schools offered algebra I and geometry, but few offered more advanced courses.

What new topics have been studied?

The Committee of Seven (Washburne, 1931) surveyed thousands of pupils in grades 1 through 8 to ascertain the mental ages at which it was most feasible to teach arithmetic topics. Even today, the curriculum shows signs of the influence of these recommendations. While less attention has been given to research on grade placement at the secondary school level, formative evaluation has continued: the work of the curriculum development projects is an obvious example of this.

Wagner (D 1961) noted that new subject matter was constantly being developed, while older content was being constantly reorganized, extended, and transformed. New content included abstract algebras, algebraic topology, lattice theories, theory of linear spaces, mathematical logic, and the general theory of sets.

Jorgensen (D 1968) questioned the emphasis on rigor in American courses compared with that in Danish courses. He suggested teaching arithmetic, algebra, and geometry concurrently, a suggestion that has been explored now and again for at least the past 40 years.

Merfeld (D 1969) tried, with some success, a unit on vectors which presented a unified introduction to linear algebra. Riggle (D 1968) showed how the concept of vector space could become a unifying thread for mathematics programs from elementary school to pre-calculus college-level mathematics.

O'Daffer (D 1969), in an exploratory study of the abilities of fifth and seventh graders to learn finite group properties and structures, ascertained that most students learned at least part of the material Most students could correctly combine transformations, but many had difficulty recognizing isomorphic groups. Hammond (D 1963) studied the understanding of seventh graders of certain principles governing operations with whole numbers. Significant relationships were found between understanding of the principles and algebra aptitude.

A systems approach, test theory, and the development of computer-managed instruction are needed components of programs featuring self-selection and self-pairing, suggested Kriewell (D 1970).

How effective are the materials from various major curriculum development projects?

The curriculum development projects have had many evaluations and comparisons made. Crespy (D 1970) analyzed 24 projects on such factors as impetus for origin, premises, content, materials developed, evaluation, and teacher training. Dahmus (D 1968) reported wide diversity in the terminology, symbols, expressions and content of algebra textbooks from four projects. Danley (D 1966) critiqued the School Mathematics Study Group (SMSG) and University of Illinois Committee on School Mathematics (UICSM) programs, comparing them on the basis of mathematical content, sequence, and pedagogical innovations.

A great many studies have focused on the SMSG materials. Williams and Shuff (1963; Shuff, D 1962) reported no significant differences at the seventh grade level between groups using traditional or SMSG textbooks. The traditional groups were favored at the eighth grade level, but after algebra, the groups with SMSG training did not differ significantly from groups who had used traditional textbooks.

No significant differences were found by Ebeid (D 1964) in achievement or attitude between groups using SMSG textbooks in grades 7 and 8 with or without self-selected activities involving a variety of mathematical materials.

Students taught with SMSG materials on measurement in grade 7 achieved as well as those in the traditional program, but were significantly superior in arithmetic reasoning (Friebel, D 1965; 1967).

Ziebarth (D 1964) found that students who had used SMSG materials for a two-year period in grades 7 through 10 made significant gains in achievement as measured by traditional tests, and did as well as those using conventional materials on all except tests of fundamental operations. Osborn (D 1966) found that study of SMSG materials for from one to three years did not result in a significant increase on arithmetic, algebra or mathematical reasoning scores, but understanding of mathematical concepts increased.

DeVenney (1969) studied the SMSG materials for low achievers. At the end of the year, eighth graders in the conventional program scored higher on a test of computational skills; no meaningful differences were found on a test of applications. The experimental group achieved significantly higher on SMSG tests, and showed a highly positive attitude toward mathematics.

Johnson (D 1966) found that use of the conventional SMSG textbook generally resulted in higher achievement than use of the programmed SMSG textbook in elementary algebra.

Little difference in achievement was found in grade 9 between classes using SMSG or traditional texts by Williams (D 1962) but some differences favoring the SMSG group were found in grade 10.

Nelson (D 1963; 1965) reported that in grades 7 and 9, no significant differences on standardized tests were found between high-ability groups who used the regular SMSG textbook for college-capable students and those who used the textbook for slow learners, but all except the highest achievers scored higher on SMSG tests when using the simplified textbook.

No significant differences in achievement were reported between one set of ninth graders using SMSG or conventional materials for algebra, but another sample using SMSG materials scored significantly higher than those using conventional materials (Payne, D 1965). Those with average and high IQ's scored higher when using SMSG materials.

Clark (D 1966) found no significant differences in achievement on either a traditional test or one using non-routine-type problems between groups taking a two-year SMSG algebra course or one year of general mathematics and one year of algebra.

Davis (D 1970) found that students using the SMSG course in coordinate geometry in grades 9 and 10 generally did significantly better than students using the regular SMSG geometry course or a more traditional course.

McIntosh (D 1965) reported no significant differences in achievement between eleventh grade groups having SMSG or a traditional program. SMSG students achieved more when taught by an experienced teacher.

Woodall (D 1967) reported a few differences favoring traditionally-taught groups in grades 4, 6, and 8, but in most cases there were no significant differences between traditional and SMSG groups.

A few studies reported on the UICSM program. Wolfe (D 1963) reported no significant differences between groups in grades 9 and 10 who used expository or discovery-oriented programmed materials after a year in the discovery-oriented UICSM program. Brown (1967) found that students using UICSM programs in solid geometry improved in their ability to visualize and draw spatial relationships. Tatsuoka and Comley (1964) reported that UICSM students achieved significantly higher than non-UICSM classes.

What test development strategies have been found to be helpful?

Romberg and Wilson (1968) discussed the development of tests for the National Longitudinal Study of Mathematical Abilities (NLSMA), an SMSG project. This involved:

(1) formulation of a scheme for classification of components of mathematical ability
(2) selection of eleven basic content areas
(3) categorization of cognitive behaviors associated with each content area
(4) solicitation of ideas for testing understanding of each behavior
(5) writing initial test items
(6) pilot testing and editing for final form

Cahen, *et al*. (1970a; 1970b) reported on the item-sampling technique for developing tests such as those for NLSMA. Instead of having all students in a sample answer all items in a pool of test items, some students answered some items and other sets of students answered other sets of items. They found that the technique was satisfactory, with the precision of estimation increasing as the number of students tested in a school increased. Reasonably close estimations of mean performance were obtained as compared to means estimated from the conventional type of testing.

Bernabei (D 1967) developed a systematic approach to the analysis of standardized achievement tests using Bloom's Taxonomy and a comparison with goals of the SMSG program.

2. ATTITUDES AND RELATED FACTORS

Do secondary school students like mathematics?

Aiken (1970b) presented a thorough review of research on attitudes toward mathematics and factors affecting those attitudes. He noted that attitudes can be traced to childhood, with evidence that they are formed as early as the third grade. The results of a number of studies indicate that attitude toward mathematics becomes increasingly negative as the students go through school.

Attitudes toward mathematics have very frequently been investigated with an instrument developed by Dutton. From a study of attitudes in grades 7 through 9, he (Dutton, 1956) reported that extreme dislike for mathematics was shown by the responses of a significant number of students (19 per cent). Most of the students (87 per cent) enjoyed problems when they knew how to work them, however, and the majority felt that arithmetic was as important as any other subject (83 per cent). Girls showed a little more dislike for mathematics than boys did. Reasons for liking mathematics included the practical aspects of the subject, the realization that it will be needed, and the enjoyment and challenge. Dislike centered on lack of understanding, difficulty in working problems, poor achievement, and its boring aspects.

In a more recent survey with junior high students (Dutton, 1968), he compared 1956 and 1966 attitudes, and found a slightly favorable change for the more recent group, which had a modern mathematics program. A revised form of the scale has also been developed. In one study using it, it was reported that about 30 per cent of the students studied in grades 6 through 8 had very favorable attitudes toward modern mathematics, 53 per cent were neutral, and 17 per cent disliked the subject a great deal (Dutton and Blum, 1968).

Using a semantic differential technique, Antonnen (1969) reported a significant positive correlation between the attitudes of students tested in grades 5 and 6 and retested in grades 11 and 12.

Amatora (1961) found that eighth grade boys were more interested in mathematics than were seventh grade boys, but girls rated it higher in grade 7 than in grade 8. Farley (D 1969) reported that boys' attitudes toward mathematics were more positive than girls' attitudes, with the difference more pronounced in grade 11 than in grade 10.

Osborn (D 1966) reported that student attitudes toward mathematics tended to become less positive the longer they studied SMSG materials. Phelps (D 1964), however, found no significant difference between the attitude of eighth graders in SMSG or traditional programs.

Not surprisingly, underachievers were found to have had lower interest and attitude scores than achievers of comparable ability (Beaton, D 1967). A significantly greater number of the parents of tenth grade underachievers indicated that they liked mathematics least of all school subjects, while parents of achievers considered mathematics to twelfth grade level important to students today.

Does a more favorable attitude lead to higher achievement?

The concern about attitudes toward mathematics stems in large measure from the belief that attitude is related to achievement. We have, unfortunately, little evidence on this from research.

Neale (1969) summarized several research studies, and noted that correlations between attitude and achievement were low. However, in the investigation of the mathematical abilities of secondary school students in twelve countries, Husen (1967) reported that attitude was positively correlated with mathematics achievement at all levels.

Spickerman (D 1970) found a relationship between attitude toward mathematics and (1) mathematics course enrollment and (2) course mark aspiration. In grade 9, course marks, but not achievement scores, were related to attitude. Low SES students tended to have less favorable attitudes toward mathematics.

Antonnen (1969) reported a significant correlation between attitude and achievement for eleventh and twelfth graders.

Significant differences were found on six attitude scales after instruction in a mathematics laboratory setting (Higgins, 1970). When data were analyzed in terms of naturally occurring groups, no significant relationship to achievement was found.

What is the relationship of teachers' attitudes to students' attitudes and achievement?

Aiken (1970b) concluded that "of all the factors affecting student attitudes toward mathematics, teacher attitudes are viewed as being of particular importance".

Ellingson (D 1962) reported a significant positive correlation of attitudes toward mathematics of students in grades 7 through 12, with teacher ratings of the students' attitudes and with achievement test scores. Phillips (D 1970) found that the type of teacher attitude encountered by a student with his most-recent teacher or for any two or three of his past three years was significantly related to his present attitude and to his achievement.

Parental attitudes were also significantly correlated with students' mathematics attitudes. Students' attitudes correlated with achievement in mathematical reasoning, concepts and computation (Burbank, D 1970).

Not all research indicates a correlation of attitude and achievement. For instance, Garner (D 1963) found teachers' attitudes toward algebra were significantly related to end-of-course attitudes of students, but not to achievement.

What is the relationship of self-concept in mathematics to achievement?

General self-concept and self-concept in mathematics were each found to be significantly related to mathematical achievement, with mathematical self-concept related significantly more to such achievement than was general self-concept (Bachman, D 1969; 1970).

Self-concept and grade point average were not found to be related for seventh and eighth graders, but a significant correlation was found between the student's self-concept of ability and his parents' perception of his ability (Birr, D 1969).

Schneider (D 1970) reported that relationships between and among self-concept of ability, achievement, and level of occupational aspiration were positive and significant at grade 9.

Does anxiety affect mathematical achievement?

Anxiety, as well as attitude, is an affective variable, and there have been attempts to analyze its impact on mathematical learning.

Loughlin, et al. (1965) found significant differences on anxiety scales between achievement levels on reasoning and fundamentals tests at varying IQ levels in grades 4 through 8.

Harte (D 1967) found that high defensive boys performed significantly higher than high anxious and low defensive boys in arithmetic achievement, with no significant differences between groups of girls in grades 2 through 8.

Eighth grade achievers had a higher level of general anxiety and more positive attitudes toward mathematics than did underachievers (Degnan, 1967).

Callister (D 1966) reported that students in conventional classes were under greater stress than those in programmed classes, but level of anxiety had no effect on comparative achievement level. Flynn (1969) found no significant differences between the achievement of students taught by programmed or conventional instruction, at any anxiety level in grades 10 through 12. MacPherson (D 1967) found that significant relationships existed between (1) anxiety and (2) time to complete programmed lessons on the language of sets.

Zamboni (D 1969) found no significant differences in achievement or test anxiety between classes in grade 11 having "relaxed" or "high stress" procedures, such as graded homework, unannounced quizzes, and no peer help. Beavers (D 1970) found differential reactions to test-taking anxiety, with boys scoring significantly higher than girls. High anxious provocation significantly lowered scores for all four personality types in grade 10. French (1962) found that differences in grade 12 in the effect of anxiety on test-taking were not consistent and rarely significant, except that girls who felt anxious did well on the mathematics test.

3. CONTENT: WHAT, WHEN AND HOW

What serves as the best predictor of achievement for algebra, geometry, and other mathematics courses?

The problem of prediction is one which has consumed a great deal of attention throughout the years. Orleans (D 1931) developed one of the first prognosis tests, and numerous studies were done to analyze its effectiveness. Table II lists some of these and other more recent studies. It is clear from the majority of studies that previous achievement (Roach, D 1967) and IQ (Dirr, D 1967) are two of the best predictors -- in other words, these are the factors which correlate most highly with achievement in any area of mathematics learning. Hanna (1966), summarizing the results of studies on geometry prediction, noted that there are limits to the usefulness of such factors. He also pointed out that in most studies, the nature of the geometry course was totally ignored, and he made a plea for considering the characteristics of the individual course as well as those of the individual student.

TABLE II

PREDICTORS OF ACHIEVEMENT IN MATHEMATICS COURSES

Author	Year	Grade	Subject	Best Predictor of Achievement
Collins	D 1968	7	mathematics	problem solving and concepts scores, then computation, reading, and language usage scores
Hall	D 1970	7-11	mathematics	marks from junior high school mathematics courses
Duncan	D 1961	8	algebra	IQ, interest scores in science and literature, algebra prognosis test scores, grade placement in computation
Hanna, *et al*.	1969	8	algebra	prognosis test scores
Barnes and Asher	1962	9	algebra	marks in grade 8 mathematics
Guilford, *et al*.	1965	9	mathematics	batteries of factor scores
Dirr	D 1967	9	algebra	IQ
McQueen and Williams	1958	9	algebra	marks in grade 8 mathematics, prognosis test scores
Osborn and Melton	1963	9	algebra	aptitude tests
Lovett	D 1969	9, 10	algebra	arithmetic achievement, initial algebra achievement

TABLE II (continued, p. 2)

Author	Year	Grade	Subject	Best Predictor of Achievement
Anglin	D 1966	10	geometry	grade 9 algebra grade point average
Babbott	D 1964	10	geometry	grades in algebra and general science plus IQ for boys, grades in algebra and social studies plus IQ for girls
Caldwell	D 1970, 1970	10	geometry	structure-of-intellect tests and algebra grades
Hanna	1967	10	geometry	student predictions, scores, grades
Mars	D 1970	10	geometry	reading comprehension and general intelligence
Kohli	D 1969	11	mathematics	aptitude tests
Hilton and Myers	1967	11, 12	mathematics	test scores

What has been ascertained about teaching the general mathematics course?

The approach used in teaching the general mathematics course has received some but limited research attention. Among the most relevant findings are the following:

(1) Howitz (D 1966) reported no significant differences between groups using expository or discovery-oriented textbooks on a standardized test, but the discovery-oriented group scored significantly higher on a non-standardized test.

(2) Maynard (D 1970) and Strickland (D 1970) reported no significant differences between groups using a non-verbalized discovery, a guided discovery, or an expository method on most units in a general mathematics program.

(3) Price (D 1966) found that tenth grade general mathematics students had better reasoning and attitude scores when they used an inductive method requiring them to form generalizations, rather than a deductive textbook-lecture method. Use of transfer materials resulted in a significant increase in critical thinking ability.

(4) Matlin (D 1960) reported no significant differences between tenth graders receiving or not receiving worksheets for one semester in general mathematics.

(5) The general mathematics course resulted in higher computation and appeared to be better for low ability ninth graders than a modified algebra course (Sederberg, D 1964).

What has been ascertained about teaching algebra?

Most of the attention directed toward algebra has been concerned with predicting achievement. However, the following are indicative of some of the other findings about the teaching of algebra:

(1) Kaufman (D 1969) surveyed 183 educators, and found that a large majority favored a deductive structuring of the subject, including basic concepts of logic and variety of methods of proof. Most textbooks did not reflect this emphasis.

(2) Teaching algebra with a discovery approach resulted in improved critical thinking scores (Ballew, D 1966).

(3) Teaching algebra verbal problem solving through use of questions resulted in greater gain in problem solving scores than did a follow-the-example method (Ashton, D 1962).

(4) Greitzer (D 1960) reported no significant differences in mastery of content between above-average students who had 24 lessons developed by the postulates of group and field theory and students who did not have these lessons in their course in grade 11.

(5) Prielipp (D 1968), in a study of the properties of an Abelian group with algebra students in grade 9, found that the commutative property was the easiest of the properties studied, followed by the identity element and inverses.

What has been ascertained about teaching geometry?

Neatrour (D 1969; 1969) surveyed textbooks in use in grades 5 through 8 and the amount of geometry in the curriculum in those grades, as well as the grade level at which various topics were taught. He noted that while the amount of geometric content varied greatly, three times as much was included as in 1900, with emphasis on informal geometry in these grades. Pruitt (D 1969) found that the number of everyday-life exercises increased from 1878 to 1959, and has decreased since. After 1938, exercises on patterns of reasoning increased.

Ahmad (D 1970), in a comparative study of the changes in the foundations and fundamental concepts of plane geometry, reported that since 1930 textbook treatments have become increasingly rigorous.

The ability of students to visualize sections of solid figures has interested several researchers. E. J. Davis (D 1970) found that eighth and tenth graders scored higher than sixth graders, with four solids and each of four cuts performed on the solids, while Palow (D 1970) found that children appeared to acquire the ability to visualize sections of solid figures (i.e., Euclidean space) at about age 12.

Boe (1966; D 1967; 1968) reported that none of the students she studied in grades 8, 10, and 12 demonstrated the ability to draw and identify geometric sections with consistent accuracy. Few were able to describe the effect of sectioning all 16 figures. Ability level and sex, but not grade level, were found to significantly affect results.

Cohen (D 1960) reported no significant differences in space perception for students who constructed models and those who did not in solid geometry in grade 12. And Cheatham (D 1970) reported no significant differences between constructing models with compass and straightedge or with paperfolding techniques.

Murray (1949) analyzed geometric ability, determining the relative contributions of spatial relations, reasoning, numerical and verbal aptitudes to geometric achievement. Spatial relations were not found to be predominant.

The focus and findings of other studies are also diverse: it is difficult to ascertain any pattern from the research -- except that some procedures are effective. For instance, dependent-prone students achieved higher geometry scores when taught by "indirect" methods such as questions and praise than by "direct" procedures involving exposition and criticism (Amidon, D 1959; Amidon and Flanders, 1961).

Usiskin (D 1970) reported that on a standardized test, scores of students using regular texts were significantly higher than scores of those using transformation-oriented texts. When the concept of dimension was emphasized, students scored significantly higher than others studying combined plane-solid geometry or only plane geometry in grade 10 (Kreigsman, D 1964).

Bundrick (D 1969) found that students using a vector approach in algebra II achieved significantly higher than those using a traditional approach on both the criterion and transfer tests. Williams (D 1966) concluded that vectors can best be used as unifying agents when taught with a linear algebra emphasis.

Bezdek (D 1967) found that students in a one-year plane-solid geometry unified course achieved as well in plane geometry as those in a one-year plane geometry course or in a one and one-half year sequence of separate courses, but the latter group scored higher on solid geometry tests.

How should operations with whole numbers and with rational numbers be taught?

While the operations with whole and rational numbers are introduced in the elementary school, not all children master all aspects -- all of the ideas and concepts, and algorithms, by the time they reach grade 7. Nevertheless, very little research attention has been paid to the way operations with whole and rational numbers are taught in the secondary school. Presumably the research on these topics which has been done with elementary school students is considered applicable at the secondary school level. Specific study of these topics is embedded in remedial courses, especially in grades 7 and 8, and in general mathematics courses.

How should ideas about percentage be taught?

The "optimal" method by which to teach percentage has been explored in several studies with seventh graders. May (D 1966) reported that a "discovery" method was most effective for immediate learning and the ratio method was best for retention. McMahon (D 1960) found no significant difference between ratio and conventional methods on tests of interpreting statements about per cent, but the ratio method resulted in greater skill in computation and greater retention.

Wynn (D 1966) found no significant differences between unitary analysis, formula, or decimal interpretations.

How should work with integers be taught?

Differences in numerical or spatial ability were not found to be related to success in learning to add and multiply with integers in grade 8; differences in verbal ability were, however, related (Tremel, D 1964). Mental age correlated most highly with gain in knowledge of signed numbers, followed by algebra aptitude, for students in grades 7, 8 and 9 (Zelechoski, D 1961).

What is the role of logic in the secondary school curriculum?

That students vary in their ability to deal with logic and proof is evident from the research. Miller (D 1968) found that the majority of the 660 students whom he tested in grades 8, 10, and 12 accepted both valid and invalid logical inference patterns as valid. In a study of students' ability to use proof, Robinson (D 1964) found that three-fourths of the 48 students in grades 7 and 9 gave at least one proof response. Most seventh graders could justify mathematical generalizations with a proof when the concepts were familiar to them. And Howell (D 1966) reported that growth in inferential reasoning ability without formal instruction in logic increased slightly across grades 7 through 9. However, fewer than one-third demonstrated understanding of half of the ten inference patterns presented.

Retzer (D 1967; Retzer and Henderson, 1967) found that the study of logic in grades 7 and 8 resulted in greater ability to verbalize mathematical generalizations, especially for gifted students. Retzer (1969) added that those students with high verbalization ability could better transfer the mathematical generalizations which they discovered.

When a unit on logic was used in classes in geometry in grade 10, no significant differences in achievement and attitude were found by Platt (D 1968). A unit on logic and proof did not affect critical thinking ability in grade 7, but there was a significant difference in grade 9 for girls immediately after instruction, and for both sexes after a two-month retention period (Hrabi, D 1968). Shumway (D 1970) found that the eighth grade class taught quadrilaterals, exponents, and operations with both examples and counterexamples scored significantly higher than the class taught with examples only.

Roberge (D 1969; 1969; 1970) investigated students' abilities to reason with principles of class reasoning and conditional reasoning in grades 4, 6, 8, and 10. Class reasoning was found to be significantly easier than conditional reasoning, though neither was consistently easier at all grade levels. Differences for content dimensions were significant: concrete-familiar was easiest, then suggestions, then abstract. Negation had a marked influence on the development of logical ability.

Smith (D 1960) made suggestions for helping students evolve a continuously more mature concept of proof as they study arithmetic, algebra, geometry, and trigonometry. His emphasis was on changes in methodology.

From a survey of geometry textbooks published since 1955 and other books and articles on mathematics, Byham (D 1970) recommended that the methods of inconsistency and of contraposition be used in secondary school mathematics.

Is the teaching of non-decimal bases effective?

Glaser (D 1970) traced the development of positional numeration systems from 1500 to the present. Review of selected textbooks for teachers and of SMSG seventh grade materials indicated that bases five and seven were most commonly used.

Why are they used? It is hoped that study of non-decimal bases will result in increased understanding of base ten, and help to decrease the errors cited by Flournoy, Brandt, and McGregor (1963). They found that the most common errors of the decimal numeration system related to: (1) the additive principle; (2) making "relative" interpretations; (3) the meaning of 1,000 as 100 tens or as 10 hundreds, etc.; (4) expressing powers of ten, as 10,000 = 10 x 10 x 10 x 10; and (5) the 10-to-1 place-value relationship.

Jackson (D 1966) reported that students receiving instruction in non-decimal numeration systems did significantly better on tests measuring understanding and problem solving skills than those studying only the decimal system in grades 5 and 7. However, those receiving instruction only on the decimal system did better in computation skills than those receiving instruction in non-decimal systems.

What can students be taught about probability and statistics?

While Beberman explored the role of the teaching of statistics in secondary school mathematics in 1952, most research attention to the topic has been more recent than that.

What secondary school students can learn about probability and statistics has been the focus of most of the research on the topic. Holmes (D 1969) found that the logic of statistical analysis by the Monte Carlo procedure was possible for bright students in grade 12.

Smock and Belovicz (1968), however, concluded that most students failed to understand the basic idea of probability theory, and Dedidow (D 1970) found that understanding of probability was not attained until grade 11.

The understanding of probability concepts has been another field of exploration. Leake (D 1962; 1965) found that students had a considerable knowledge of probability concepts such as the probability of a sample space, a simple event, or the union of two or more mutually exclusive events, before being taught them. Leffin (D 1969) also reported that students in grades 4 through 7 had acquired a considerable knowledge about points of a finite sample space, probability of a simple event, and quantification of probabilities, and could apply these concepts in a variety of situations.

Smith (D 1966) found no significant differences between groups taught or not taught a unit on probability and statistics at the seventh grade level, but some topics seemed to be appropriate for most students: possible outcomes of an experiment, probabilities of events that are equally likely and events that are not equally likely, mutually exclusive events, Pascal's triangle, histograms, continuous and discrete data, central tendency, and measures of variation, particularly the range.

What other topics have been studied?

Among the most pertinent findings related to other courses and newer topics are:

(1) Reeves (D 1970) reported that in secondary school textbooks, function was generally developed as a set of ordered pairs, in very abstract form.

(2) Thomas (D 1970), in an analysis of stages in the attainment of the concept of function, found that capable students at ages 11-14 could reach a relatively high level and many could achieve understanding at an initial formal operational level.

(3) Nelson (D 1969) found with eighth graders that a visual approach to the concept of function was more effective than verbal, numerical or eclectic procedures on tests designed for each. There was no evidence to indicate an interdependence between the three abilities and corresponding approaches; numerical ability was a better predictor.

(4) Izzo (D 1957), who analyzed 627 textbooks, noted that graphs first appeared in trigonometry textbooks in 1826 and in algebra textbooks in 1883. Attention to graphs since 1900 has been tremendous.

(5) Text materials for a course in analytical trigonometry using vector methods from geometry were written and adapted by Szabo (D 1970). The feasibility of such a course was verified in classroom trials.

(6) Wallace (D 1969) reported that reviewing trigonometry using flow charting and elementary computer techniques was effective.

(7) A unit with a rigorous development of the real number system was feasible for above average students with a strong background in mathematics (Taylor, D 1970). Scores of a high school analytic geometry class were significantly higher than those of a college class.

(8) Buchanan (D 1965) found favorable attitudes toward a course on limits in grade 12. Isaacs (D 1962) reported that a unit on the limit concept, developed as preparation for calculus, was successful with twelfth graders.

(9) Hight (D 1962) found that a rigorous treatment of the limit concept, as found in college calculus texts, was embedded in revised SMSG textbooks.

(10) A deductive program for teaching the derivative concept or the limit and derivative concepts together in beginning calculus was better than an inductive program (Lackner, D 1969).

(11) Riggs (D 1969) reported that twelfth graders were successful with a unit on the mean value theorem, but ninth graders were not successful.

(12) Pinker (D 1969) developed a course on the calculus of finite differences which was successful in providing students with meaningful practice on algebraic manipulation.

What factors are related to problem-solving ability?

Alexander (D 1959) studied the relationship of selected factors to the ability to solve problems in arithmetic, studying a group of 623 students in grade 7. He found that ability to understand verbal concepts, mental age, reading comprehension and vocabulary, arithmetic concepts and computation, intelligence, ability to analyze problems, ability to interpret data, perception of relationships involving comparison of data, and recognition of limitations of given data appeared closely related to arithmetic reasoning. Going beyond the data and crude errors in interpreting data were associated with low achievement. Martin (D 1964) concluded that skills in reading, reasoning, process selection, and computation interact and are crucial in the solution of problems in a verbal context.

Kilpatrick (D 1968) asked 56 students in grade 8 to think aloud as they solved problems, and then coded their answers. He found that measure of quantitative ability, mathematics achievement, word fluency, general reasoning, and a reflective conceptual tempo were positively correlated with students' use of equations in solving word problems. Attitude toward mathematics was not correlated with the coded variables.

Several studies have indicated that when verbal problems were presented as computational items, more students were able to answer them correctly. Students' ability to select procedures for solving non-numerical problems was not as great as the ability to solve similar numerical problems in grades 7 through 9 (Welker, D 1963).

Kennedy, Eliot, and Krulee (1970) reported that numerical problems offered little difficulty, but algebraic word problems were more difficult for less-able students. Both able and less-able students recognized the relationships needed for equations, but less-able students did not identify logical or physical inferences as well and were likely to process information sequentially.

Some specific problem solving techniques have been found to be helpful:

(1) Teaching students to ask a set of questions about problems to be solved helped more than showing them how to solve a particular type of problem and then giving practice (Ashton, D 1962).

(2) Use of tables in organizing the information presented in a problem helped pupils to develop equations for solving problems (Denmark, D 1965).

(3) Practice on problem solving using tape recordings resulted in improvement in the ability to extract and retrieve information, combine operations, and give correct responses (Sekyra, D 1969).

(4) Word problems with accurate pictures aided students (Sherrill, 1970).

(5) Instruction on solving problems with extraneous data resulted in better problem solving scores than did instruction with problems having no extraneous data (Bechtold, D 1965).

Travers (D 1966; 1967) reported that students preferred social-economic, mechanical-scientific, and abstract problem solving situations, in that order, with the preference of the ninth graders studied related to their interests. It was also reported (Travers, Heath, and Cahen, 1967) that students preferred a symbolic mode of representation to verbal and graphic modes.

Baughman (D 1968) presented the following criteria for developing material that promotes the development of general heuristic cognitive patterns:

(1) Problem situations must be based on some important structural or organizational idea that remains to be discovered by the student.

(2) Problem situations must provide elements to create information that does not match the student's anticipated result or his world of experience.

(3) Problem situations must contain the unknown element embodied in an unknown process, idea, principle, concept, postulate, or theorem that contributes to the eventual structure of mathematics.

(4) Problem situations must contain only that minimal data which, through application of analysis and heuristic reasoning, will eventually reveal the relationships inherent for problem solution.

(5) Problem situations must be based on a search for a pattern or condition that reveals the interconnection between the data and the unknown.

Wilson (D 1968) reported that for training tasks, problem solving performance on functions and geometry tended to be independent of the level of generality of the heuristics. Students appeared to benefit on transfer tasks from having a wide range of heuristics available.

What tests of Piaget's theory have been made with secondary school students?

Piaget has theorized that there are certain stages of development through which children move, and much research on children aged 3 to 8 and slightly beyond has been concerned with ascertaining (a) whether these stages are accurately determined, and (b) whether children react to Piaget's tasks as he says they do. Far less attention has been given to this type of research at the secondary school level. Frequently, researchers discuss their findings in terms of Piaget's theory, but less frequently have they designed their research to test this theory.

Among the studies which have been directly concerned with Piagetian theory are the seven that are cited below. It is obvious that no clear pattern can be determined from such a limited number.

(1) Elkind (1961) reported that 87 per cent of the students he tested in grades 7 through 12 had abstract conceptions of mass and weight, but only 47 per cent had an abstract conception of volume. More boys than girls had attained the volume concept.

(2) Leskow (D 1969) reported strong support for Piaget's use of the mathematical group as a model for the cognitive structures underlying permutation skills at ages 12, 15, and 18.

(3) Golledge (D 1966) found that many students below age 16 had not mastered either formal or concrete reasoning, although improvement was evident with age. The formal reasoning scores progressed in a way consistent with Piaget's theory, but concrete reasoning items appeared to be more difficult than he described.

(4) Rimoldi, Aghi, and Burder (1968) found that problem-solving "logic" increased with age and was interactive with language.

(5) Phillips (D 1968) reported significant differences in task attainment between grade levels, but no significant differences between the two types of presentation (object and graphic), on tasks of displacement volume, at grades 3, 5, and 7.

(6) Glick and Wapner (1968) found that correctness and justification of answers for verbal and concrete transitivity tasks reflected: (a) an increase in transitivity reasoning with age, (b) concrete tasks solicited more correct responses but fewer adequate justifications; and (c) no apparent association of correct responses and adequate justifications.

(7) Needleman (D 1970) reported that a developmental scale of space and measurement concepts prerequisite to understanding rectangular area and its computation was found to exist, with a significant relationship between acquisition of the concept of area and that of operational continuity for ages 8 through 14.

4. INDIVIDUALIZING INSTRUCTION

Is grouping an effective way of providing for individual differences?

That a wide range of individual differences exists among students is apparent to everyone. The teacher can't and shouldn't try to eliminate these differences. But he does need to identify them and then try to "meet" them. And one of the ways to meet them is with various methods of grouping. These have ranged from intra-class patterns within a self-contained, heterogeneous class to ability-grouped homogeneous classes.

Three major problems must be faced before anyone concludes that homogeneous grouping is the "best" way to face the problem of how to cope with individual differences. First, as Balow (1964) concluded, one cannot create homogeneous groups and, if one could, such groups would not remain homogeneous. Thus, second, flexibility needs to be maintained in grouping. And, third, curriculum changes must take place if any form of grouping is to be effective.

Results of some of the studies comparing homogeneous and heterogeneous grouping are found on Table III. Not included on the table is a study by Paulson (1964) who found that homogeneous groups scored higher than heterogeneous groups on algebra achievement. Heterogeneous groups receiving public display of performance scored significantly higher gains than any of the other groups.

Various other types of grouping have also been studied. Bierden (D 1969; 1970) and Mortlock (D 1970) reported that a combination of whole-class instruction and flexible intra-class grouping based on the achievement of behavioral objectives resulted in significant gains in computational skills, concept knowledge, and attitudes, as well as a reduction in anxiety.

Nix (D 1970) found that students in grade 8 with low IQ, those with average mathematical ability, and boys achieved significantly more under individual instruction than under group-oriented instruction.

Snyder (D 1967) reported no significant differences in achievement or in characteristics of students in grades 7 and 8 who selected either of two independent work approaches, though gains were greater than for students in regular classes.

Students in grades 7 and 8 who worked in three-member teams achieved significantly better than those who worked individually (Pearl, D 1967).

Banghart and Spraker (1963) and Spraker (D 1961) reported no significant differences between group and individual work on measures of creativity.

Fitzgerald (1965), in a study with students in grades 7 and 8, found that bright students (those with IQ's of 115 and over) did not learn as much in self-selection classes as in conventional classes. Those with IQ's below 115 learned equally well in both classes.

TABLE III

STUDIES ON HETEROGENEOUS OR HOMOGENEOUS GROUPING

Author	Year	Grade	Results
Alam	D 1969	9	students in a separate program were significantly better in applications than those in the regular program
Bailey	D 1968	9	no significant differences between homogeneous or heterogeneous groups
Mahler	D 1962	7, 8	no significant differences between homogeneous or heterogeneous groups
Mikkelson	D 1963	7, 8	no significant differences between homogeneous and heterogeneous groups when neither was accelerated, but acceleration was a time-saver
Willcutt	D 1967, 1969	7	no significant differences between homogeneous self-contained groups or heterogeneous groups using team teaching

What is mathematical ability?

A positive relationship between mathematical ability and general intelligence has been found by many researchers. However, what mathematical ability includes -- what factors are involved -- is a matter of continuing investigation.

Kim and Leton (1966) concluded from a survey of ninth grade boys that mathematical ability is comprised of a number of aptitudes and is not simply a unitary trait. Kennedy and Walsh (1965) stated that it appeared to be not a specific ability, but related to overall high ability.

Williams (D 1967) added to this with his finding that students in grades 10 and 11 who were gifted in mathematics had similar patterns of performance and were similar on divergent production to those gifted in other areas.

However, Bree (D 1969) reported that two "profiles" of the pattern followed while thinking aloud geometry proofs from the same student were more similar than two from different students. He found that "understanding" appeared to be composed of the simpler processes of consolidating, rephrasing, explaining, and predicting the steps of the solution.

Van Horn (1966) concluded that it appeared that the abilities which are most important in mathematics are those requiring cognition and convergent production.

What mathematical errors are most commonly made by secondary school students?

Little attention has been paid in recent years to error analysis. Guiler and Grossnickle were concerned with it several decades ago, and Bernstein (D 1955) indicated that 80 per cent of the errors with fundamentals made by ninth graders were in three categories: the use of zero in multiplication and division, borrowing in subtraction, and understanding of the decimal point in all four operations. On an 18-item test measuring ability to apply basic properties in operations with whole numbers, Flournoy (1964) found that seventh graders had an error rate of 50 per cent or greater on ten of the items. Items on the distributive property were most frequently missed.

What types of programs and materials are effective for slower learners and underachievers?

Much attention has been given on how to provide for remedial and disadvantaged students -- use of self-instruction, tutors, and special programs.

Programmed materials on computation skills, selected to meet the diagnosed needs, aided underachievers more than regular classroom practices (Scott, D 1970). Bobier (D 1964), however, concluded that low-achieving students of limited ability were not sufficiently motivated to use programmed textbooks in basic skills on an independent study basis.

Sherer (D 1968) developed some materials using instructional aids such as drawings, counters, and number lines and charts. The low-achievers using these materials with tutors gained significantly in arithmetic achievement.

DeVenney (1968) developed, with low achieving seventh and eighth graders, a program incorporating daily worksheets, partially programmed lessons, and the use of tables to aid in computation. Students using these materials did significantly better on most SMSG tests and on attitude scales, but did less well than those using conventional textbooks on standardized achievement tests.

Easterday (1964) organized SMSG and traditional materials into a program for low achievers in grades 7 and 8. On a standardized achievement test, these students made a normal increase during the year, working in small groups.

Kleckner (D 1969) found that slow learners in grades 9 and 10 taught by conventional methods achieved more than classes taught by discovery-type strategies in a mathematics laboratory setting.

Gibney (D 1962; 1962) reported that review lessons on multiplication aided the retention of seventh grade slow learners.

Herriot (1967; D 1968) had students in grades 7 and 9 who were classified as slow learners study materials for two years. They achieved a greater gain than a high-ability group achieved in one year. Thus the pace of instruction affected achievement scores of slow learners.

Tutoring appeared to help those being tutored. Anderson (D 1970) found that tutoring itself did not increase proficiency, but the special instruction in multiplication and division skills needed by junior high school students for tutoring fifth graders resulted in significant gains in achievement.

What types of programs and materials are effective for faster learners?

Enrichment programs were found in most schools in various studies, in the form of ability grouping, special courses, or coaching groups.

Attention in recent years has been directed to acceleration, not only comparing types of programs but also analyzing the effects of acceleration.

Ray (D 1961) concluded that both enrichment and acceleration were beneficial for eighth and ninth grade students. Goldberg, _et al_. (1966) found that acceleration resulted in greater achievement than did enrichment in grades 7 through 9. However, Berman (1965) found that eleventh graders in the enriched three-year junior high school program achieved significantly higher mathematics grades in the secondary school than students in a two-year accelerated program.

Accelerated students in grade 12 achieved nearly as well as their older course-peers on tests, but had lower mathematics grade averages and lower attitudes (Fredstrom, D 1965). Rusch and Clark (1963) found that the arithmetic achievement of an accelerated group was higher than that of a non-accelerated group in grade 8.

Friesen (D 1961) found that talented eighth graders achieved as well or better in algebra than ninth grade students. Ludeman (D 1970) reported that twelfth graders in the accelerated program generally achieved significantly higher than those in the standard program.

Klausmeier and Wiersma (1964) found that bright students who took three years of work in two years achieved as well in algebra as those in the regular program, but less well in geometry.

Some factors involved in successful advanced placement programs were identified by Beougher (D 1969): operation of calculus classes, guidance, use of outside consultant advice, SES, and to some extent, teacher background in mathematics.

What personality factors have been found to be associated with mathematical achievement?

Swafford (D 1970) classified eighth grade students into four groups on the basis of achievement, and then identified six personality factors which distinguished among the groups.

Haggard (1957) identified specific characteristics of a group of high achievers in mathematics in grades 3 through 9. He found that they tended to view their environment with curiosity, felt capable, had the best-developed and healthiest egos, could express feelings freely, were emotionally controlled and flexible, and showed the most independence of thought. Kochnower (1961) reported that students whose mathematics achievement exceeded their average achievement had a tendency to react emotionally, and could be characterized as non-conformists.

Carlow (D 1968) investigated the influence of conceptual structure, practice, and the learner's personality. The personality factors of conceptual level and submissiveness appeared to be important in guided discovery learning for ninth grade boys.

Ayers, Bashaw and Wash (1969) reported that correlations of personality factors with mathematics achievement in grade 10 were low. Good mathematics students tended to be withdrawn, conscientious, emotional, immature, and lacking in frustration tolerance.

High ability in mathematics appeared to be related to factors on personality tests which can be described as awareness of power structure, concern with theoretical rather than social issues, and emotionality (Kennedy and Walsh, 1965).

Do boys and girls achieve differently?

In some instances, on some measures, there appears to be a difference in the achievement of boys and girls -- but the converse is also true.

Alexander (1962) found no significant differences between girls and boys on problem solving ability in grade 7, and Powell, *et al*. (1963) found no significant differences between sexes for either arithmetic reasoning or fundamentals in grades 2 through 8.

Cragg (D 1967) reported that boys scored significantly higher than girls on mathematics tests, and Powell, O'Connor, and Parsley (1964) reported that boys, especially those with IQ's of 115 or more, scored higher on arithmetic reasoning tests in grades 4 through 8.

Koopman (D 1964) found that boys made significantly more correct, as well as more incorrect, evaluations of their problem solving accuracy as did girls, who were more unsure of their solutions. The sex difference on correct evaluations diminished and incorrect evaluations increased with age, though twelfth graders made more correct and fewer incorrect evaluations than did ninth graders.

White and Aaron (1967) found that girls appeared to be more sensitive to the motive-arousing cues of mathematics teachers and more in fear of failure. Significant differences in perception of achievement cues were also found among achievement-level groups and between sexes.

Gay (1969) found that eighth grade girls who received a variable number of examples retained significantly more than those in groups where the number was fixed or at choice. Boys retained more when they could choose.

What is the effect on achievement of factors such as socioeconomic level (SES)?

Johnson (D 1967) found few significant differences between students of low and high SES.

Dreyfuss (D 1969) reported on a special program which included such activities as: field trips, students working with teachers individually and in small groups; a counselor evaluating students' work each week; programmed texts, records, and tapes; independent study; students working with tutors; individual student projects; guest speakers; and the use of special equipment. Those in the special activity program achieved significantly higher test scores, though grades in mathematics were not different from those in the control group.

Houston (D 1969) found that IQ and sex have a significant relationship to performance in arithmetic computation for pupils who were previously enrolled in a compensatory education program in inner city schools.

In a longitudinal study, reported in 1960, Osborne found that differences in the arithmetic achievement of white and Negro pupils increased between grades 6 and 10. A gap of one year existed at grade 6; two years, at grade 8; and four years, at grade 10. In a later study, Osborne and Miele (1969) reported that environment did not play a significantly greater role in the development of numerical ability among Negro achievers than among white children ages 13-18.

Prichard (D 1970) examined certain indicators of achievement during the progress of racial desegregation in a school system. White students achieved significantly higher than Negro students; no significant effects were found after desegregation for either group. Significant positive changes in achievement were found in grades 5 and 7 for Negroes and in grade 5 for Whites.

5. INSTRUCTIONAL MATERIALS AND MEDIA

What are some characteristics of mathematics textbooks?

The study of textbooks has shifted from mere assessment of contents to analysis of important facets. For instance, Buchalter (D 1969) analyzed 45 textbooks for grades 7 through 14. She noted that the presentation of the structure of mathematics was more often at the two lowest levels of cognitive learning -- knowledge and comprehension -- than at the four highest levels -- application, analysis, synthesis, and evaluation.

Ginther (D 1965) studied definitions; connotative definitions were used most commonly, with geometry textbooks having a greater proportion than algebra textbooks.

Discovery procedures used in text materials for grades 6 through 8 generally dealt with the development of concepts rather than operational procedures. They did not always require a high degree of involvement, however, nor were they always inductive (Lohr, D 1969).

In one study, the characteristics of textbooks which are particularly important to certain groups of learners were studied. For middle and upper ability students, achievement on modern topics was enhanced by use of a textbook which includes more explanation and more discussion of subject matter, made greater use of symbolic notation, and provided more examples with the explanatory material (McLaughlin, D 1970).

Recent analysis of the readability of textbooks has provided some interesting findings. Shaw (1967), in a study of reading problems in mathematics textbooks, found that there was great internal variation of reading level in all textbooks for grades 1 through 8. In grade 7, high-ability texts had a fifth to sixth grade reading level, low-ability texts had a seventh grade reading level, and middle-ability texts had a ninth to tenth grade reading level. It seems apparent that vocabulary was not a carefully controlled factor in these textbooks.

Smith (1969) found that only six of eleven seventh grade mathematics textbooks and five of eleven eighth grade mathematics textbooks had a reading level appropriate for the grade of their intended use.

The National Longitudinal Study of Mathematical Abilities (NLSMA) involved an attempt to determine the effect of different types of textbooks on student achievement. In general, as Begle reported in the 1970 NSSE Yearbook, the higher the grade level, the less seems to be the effect associated with the textbook.

What is the effect of televised instruction?

Televised enrichment lessons resulted in significantly increased achievement scores for both algebra and geometry classes, with no consistent pattern found in comparisons for level of ability by type of grouping or for type of instruction in grades 9 and 10 (Berger, D 1962).

Jacobs and Bollenbacher (1960) found that those with average ability gained more from television instruction, while those with high ability did better with conventional instruction. No significant differences were found at the lower ability level. Attitude improved in grade 9 when television was used, according to Westley and Jacobson (1963).

No significant differences between tenth grade classes taught only by a teacher and those in which television was used were found by Geddes (D 1962).

How helpful is the use of other materials?

Few studies have provided specific information on the effectiveness of other materials.

The regular use of mathematical games resulted in significantly different attitude scores, but no substantial relationships were found between attitude and achievement or ability, or between SES and achievement or attitude (Burgess, D 1970).

Jamison (D 1963; 1964) working with three classes in grade 7, found no significant differences between groups who were instructed with only a large abacus used by the teacher or also with smaller student-manipulated abaci or with no abacus on numeration systems other than base ten.

Taped instruction was studied by Robinson (D 1969), who reported that seventh graders who received traditional instruction performed better than those who received tape instruction. Sekyra (D 1969) found that practice in problem solving using taped lessons resulted in significant improvement in problem solving skills.

Schippert (D 1965) found that students in grade 7 in an inner-city school had significantly higher achievement when they used a laboratory

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approach in which they manipulated actual models or representations of mathematical principles, than when they were taught with verbal or written descriptions of those principles.

Schnur (1969) reported that the use of attribute blocks did not enhance a reflective learning style.

What is known about the effect of programmed instruction?

Programmed instruction has been used in many studies because it allows the researcher to control the variables, ensuring that every student has the same, planned treatment. Frequently, these studies have not been done to increase knowledge about some phase of mathematics instruction per se, but to secure information on some generalized variable. Table IV lists some of these, in which the program was on a mathematical topic but the variables such as format or sequence were the focus. A study by Bivens (1964) is another example of this type. He compared groups who were given feedback that was explicit or that required interpretation for programs on set theory, and reported no significant differences.

Table V lists another type of study, those which compare programmed with conventional instruction. While findings from such studies may be applied in the classroom situation, it is obvious that the results are equivocal.

Studies that use programmed instruction can provide meaningful information for mathematics teachers. Some have been cited before this. Another is that of Brown (D 1968), who concluded, after use of programs on the computation of the derivative of an algebraic expression and the multiplication of vectors with tenth graders and college students, that interaction between ability and content-presentation form existed. Maximum achievement occurred when content form was congruent with a pattern of semantic and symbolic ability factors (although these were not clearly presented).

Lack (1970) found that for students matched for sex and IQ in grade 7, achievement and attitude were generally higher for those using programmed workbooks than for those having teacher-led work on sample exercises.

TABLE IV

STUDIES ON FORMAT, SEQUENCE, AND RESPONSE VARIABLES USING PROGRAMMED INSTRUCTION

Author	Year	Topic	Grade	Length	Variable	Results
Bassler	1968	integers, moduli, vector arithmetic	4, 6, 8	--	type of format	linear with high level of guidance better than branched
Beane	D 1963, 1965	plane geometry	10	2 wks.	type of format; type of response	no significant differences between linear and branched; no significant differences between multiple choice or constructed response
Oates	D 1966	binary arithmetic	junior high	6 days	type of format	no significant differences between linear and "auto-elucidative"
Peters	D 1964	geometry	10	--	type of format	no significant differences between linear and branched
Brown	1970	trigonometry	10, 11	2 days	type of sequence	logical sequence better than scrambled
Miller	1969	mathematics	8, 12	1 wk.	type of sequence	non-logical sequence better in grade 12, no significant differences in grade 8
Nelson	D 1962	mathematical induction	8	6 days	type of sequence; type of response	no significant differences between fixed and variable sequence, or between multiple choice and constructed response

TABLE IV (continued, p. 2)

Author	Year	Topic	Grade	Length	Variable	Results
Niedermeyer, Brown, and Sulzin	1969	mathematics	9	2 days	type of sequence	logical sequence better for error rate; no significant differences for achievement
Wiebe	D 1966	general mathematics	9	5 days	type of reinforcement	immediate reinforcement with teacher better than delayed reinforcement or program only with immediate reinforcement

TABLE V

STUDIES COMPARING PROGRAMMED WITH CONVENTIONAL INSTRUCTION

Author	Year	Topic	Grade	Length	Results
Biddle	1967, D 1967	geometry	10	1 yr.	no significant differences for most groups
Blair	D 1964	algebra	9	--	conventional better
Brown	1964	--	9	--	conventional or programmed followed by conventional better than programmed only
Coulson	1967	geometry	10	--	no significant differences between monitored programs or augmented activity by teacher
Davis	D 1967	algebra	9	--	no significant differences between programmed with or without lecture and supplementary materials
Devine	D 1967, 1968	algebra	9	1 yr.	conventional better when teachers were average to above average, programmed better than inexperienced or below average teacher
Easterday and Easterday	1968	general mathematics	9	1 yr.	programmed better, especially for lower achievers and for boys
Johnston	D 1969	--	7	--	no significant differences between programmed and conventional
Lucas	1967	algebra	8	2 yrs.	no significant differences between programmed and conventional

TABLE V (continued, p. 2)

Author	Year	Topic	Grade	Length	Results
Meadowcroft	1965, D 1965	--	7	1 yr.	no significant differences between conventional with or preceding and following programmed
Meadowcroft	1965	--	6, 7, 8	2 yrs.	no significant differences between programmed and conventional
Moses	D 1962	algebra	9	1 yr.	programmed more effective than conventional for those with high ability
Raymond	1963, 1964	algebra	9, 10	--	no significant differences between programmed and conventional
Robson	D 1966	algebra	9	1 sem.	conventional better
Sneider	1968	--	9	--	conventional better
Tanner	D 1966	arithmetic fundamentals	7	1 sem.	no significant differences in fundamentals, conventional better for reasoning and problems
Wriggle	D 1965	set theory	9	--	programmed with review questions better than other programmed or conventional

Does the use of desk calculators affect achievement?

The results of studies on this topic are variable. The use of desk calculators to check paper-and-pencil computation for seven weeks in grade 9 resulted in no significant differences in scores on tests of attitude and computational skills (Cech, D 1970), and Ellis and Corum (1969) also reported no significant differences for the group using calculators. Used only in class for nine weeks in grades 6 through 8, calculators had no effect on achievement except for seventh grade reasoning scores, nor did they affect correction of errors, according to Durrance (D 1965). Mastbaum (D 1969) found that students in grades 7 and 8 learned to use the calculator to solve one-step computation problems, but this ability did not transfer to non-calculator situations. Neither achievement nor attitude was significantly improved.

Keough and Burke (1967), however, found that the group using calculators in grades 11 and 12 achieved significantly more than a group not using them.

Findley (D 1967) reported that use of a traditional textbook plus calculators for a full year resulted in significant gains, greater than those for students using the traditional text alone or the modern text with calculators, but only on arithmetic fundamentals.

What is the role of computers in the instructional process?

Despite the data-collecting potential of computers, little more is known from studies using tutorial computer-assisted instruction (CAI) programs with secondary school students than that students can learn from such materials.

Surprisingly, there isn't a great deal of evidence on non-tutorial uses, either. In a two-year study, Hatfield (D 1970) reported some significant differences favoring those who used computer programming with BASIC in grade 7. During the first year, significant differences were found between groups who used computer-programming and those who did not on only one of 11 criterion tests. Learning of the programming language seemed to interfere with concurrent study of numeration systems. During the second year, significant differences favoring the computer group were found on three of 12 tests, with high and average achievers especially favored. The number theory unit seemed particularly relevant for computer use.

Kieren (D 1969), in a replication of this experiment with eleventh graders, conducted a two-year study involving 81 students enrolled in intermediate mathematics. In one class the students wrote computer programs and used the output from the computer to which they had remote access via a teletype terminal. The other class each year used conventional teaching-learning patterns without computer-use. There were significant differences favoring the computer group on two tests and favoring the conventional group on another. He concluded that use of the computer might have a relatively stronger affect on the achievement of average students than of high-achieving students, and appears to contribute to the learning of complex processes, organization and relation of data, and infinite processes.

Wallace (D 1969) studied the impact of computer mathematics on the learning of trigonometry. In grades 11 and 12, Class I was taught trigonometry conventionally; Class II was taught a semester course in computer mathematics, then trigonometry as for Class I; and Class III was taught 15 weeks of trigonometry, then was given review for three weeks during which flow chart and elementary computer techniques were used as another means of learning trigonometric relations and problem solving. The Class III students showed significantly more gain in knowledge of trigonometry. The use of flow charts and algorithmic methods in teaching appeared to "fortify" conventional teaching methods, so that higher learning rates were attained.

Washburn (D 1969) coordinated programming exercises with the mathematical topics of a particular course at the seventh, eighth, twelfth, and college freshman levels. The students in the experimental classes were taught the elements of the CUPL programming language as they were needed for the programming exercises. The writing, execution and correction of computer programs was found to strengthen understanding of mathematical concepts and result in strong positive attitudes.

6. TEACHER EDUCATION

What is effective in pre-service education?

The years of pre-service education for teachers are particularly important. Mathematics course requirements have increased in recent years (Fisher, 1968), and many studies have determined the background being attained in specific college programs.

Wong (D 1969) found that a majority of college mathematicians and educators in 130 institutions expressed satisfaction with current geometry preparation programs, but also recommended changes. They favored emphasis on transformations, proof and rigor, and methodology. Having only one geometry course was not found to affect attitude toward geometry by pre-service teachers.

Of even more importance, concern has been focused on the student teaching program, and in particular on teaching behaviors and how to improve them. For instance, Steinen (D 1967) ascertained that feedback helped student teachers to improve, with that from peers and students apparently most helpful.

Moser (D 1966) reported that a specialized observational technique used with sound tape recordings proved effective in collecting objective data on student teacher performance. The student teachers were found to establish a consistent teaching style and to be hesitant to exert overt disciplinary control. Those using SMSG or UICSM texts had the highest amount of spontaneous student participation.

Flora (D 1970) developed an instrument which differentiated between teachers of high and minimal effectiveness. It could be used to predict success in student teaching or to indicate specific needed changes in teaching behaviors.

What in-service education procedures are effective?

There have been many surveys of the effect of NSF summer institutes and academic year institutes. Generally, teachers have reported satisfaction with them. They feel that their mathematical background increased and that participation benefited them in terms of professional advancement.

Some other in-service programs have also been assessed. For instance, Byrkit (D 1968) found no significant differences between groups studying concepts of integers by videotape or by only the soundtrack from the videotape, but the videotape group did better on pedagogical questions related to the lesson on elementary number theory.

McDermott (D 1967) designed three supplementary units involving mathematical models using a physical situation, for use in in-service programs. He stated five recommendations for those who would develop such materials, and these are actually generalizations that teachers should keep in mind as they use such materials:

(1) Mathematical models should not be implicit in the description of a situation.

(2) Some concrete models of abstract concepts should be developed so that the student does not view all modeling as going from the concrete to the abstract.

(3) Some physical situations should be described in which complete reliance on the observable or intuition would lead one astray, whereas the mathematical model is free from prejudices of physical experience.

(4) Some physical situations should be described and analyzed in detail.

(5) No set of materials should leave the impression that mathematics exists only because of its applications.

Many studies have assessed the background of teachers, but, as with pre-service education, much attention has been focused on teaching behaviors. Wood (D 1969) reported that the group having in-service instruction in interaction analysis became significantly more direct in their verbal behavior in the classroom, but did not significantly change attitudes.

Cooney (D 1970) analyzed transcripts from 44 classroom sessions to develop a description of ways that mathematics teachers assist students in organizing their cognitive knowledge through deduction, induction, classifying, and analyzing.

What strategies and behaviors have teachers used?

Wolfe (D 1969) analyzed the types of strategies used in algebra, general mathematics, and geometry classes. A strategy of validation, a subsumming generalization to justify an assertion, and deductive proof were used most frequently.

Kysilka (D 1970) found that mathematics teachers asked more convergent and procedural-positive questions, made more directing and describing statements, rejected fewer student responses, and talked more than social studies teachers. Students volunteered less frequently in mathematics classes.

Hernandez (D 1970) noted great variability among teachers in their cognitive content of statements. The predominant cognitive process used was memory; there was little convergent and almost no divergent discourse. Classification, Narration, and Evaluation were coded most frequently.

Fey (D 1969) analyzed tape-recorded lessons to develop a profile of verbal activity in certain classes, with patterns described through the use of an instrument identifying interaction components. Teachers were found to speak more than students, leaving responding as the major student activity.

Stilwell (D 1968) found that teacher talk consumed approximately three times as much time as student talk; less than three per cent of all time in problem solving involved the method of solving a problem. Approximately eight per cent of the time was coded as silence . . .

How do teacher background and teacher behaviors affect students' achievement?

Kester (D 1969) found that teachers communicated with allegedly bright pupils in grade 7 in a more friendly, encouraging, accepting manner. Student achievement, IQ, and attitude were not significantly affected by teacher expectations, however.

Peskin (D 1966) reported that on both arithmetic and geometry in grade 7, significant positive correlations were found between teachers' understanding scores and students' achievement scores, but not between teachers' attitude scores and students' attitude or achievement scores.

Rouse (D 1968) found low positive correlations between student achievement and teacher experience and high school preparation. A low negative correlation was found between teacher's mathematics preparation and students' achievement from kindergarten through grade 8. Smith (D 1965) found that differences in the mathematical preparation of teachers had no apparent influence on the mean arithmetic achievement of students in grade 8, but differences in professional-education preparation had a positive influence. Soeteber (D 1970) found that students achieved more when they were taught by mathematics teachers with more than two years of experience, a high grade point average, and above average knowledge.

APPENDIX A

ALPHABETICAL LIST OF ARTICLES AND ERIC DOCUMENTS ON SECONDARY SCHOOL MATHEMATICS

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	17	1970	Suydam		
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Journal for Research in Mathematics Education	2	1971	Suydam and Weaver	articles, dissertations	K-12
School Review	41-47	1933-39	Breslich	articles	7-12
	48-64	1940-56	Hartung and/or Hawkins		
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APPENDIX B

ALPHABETICAL LIST OF DISSERTATIONS ON SECONDARY SCHOOL MATHEMATICS

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Treuenfels, Edith Sophie. Reflections of Pragmatic Philosophy in the Literature on Mathematics Teaching. (U. Wisconsin, 1957.) *Dis. Abst.* 17: 2534-2535; Nov. 1957. (d-1; m-1)

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Truax, Robert Lloyd. A Study of Factors Which Influence Curriculum Change in Secondary School Mathematics. (Oklahoma State U., 1964.) *Dis. Abst.* 26: 1438; Sept. 1965. (b-3)

Tucker, Joseph. A Junior High School Level Experiment on Developing Algebra Readiness by the Use of Finite Non-Numerical Algebraic Systems. (Auburn U., 1969.) *Dis. Abst.* 31A: 1154; Sept. 1970. (b-2; b-3, c-22, c-30, f-2c)

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Turner, Marguerite Elizabeth. Construction, Validation, and Use of a Test for Measuring the Concept of Shape in Grades One Through Nine. (U. Connecticut, 1961.) Dis. Abst. 22: 2701-2702; Feb. 1962. (f-1a; c-8)

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Volchansky, Paul Robert. The Effects of Two Mathematical Instruction Approaches on Analytical Cognition. (U. New Mexico, 1968.) Dis. Abst. 29A: 4396; June 1969. (a-4; g-4)

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Waggoner, Sherman G. The Ability of Pupils to Interpret Certain Basic Ideas in Linear Equations. (U. Iowa, 1932.) (c-22)

Wagner, John, Jr. Some Aspects of Modern Mathematics. (U. Texas, 1960.) *Dis. Abst.* 21: 1810-1811; Jan. 1961. (b-3)

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Wales, Lois Tyler. A Recommended Program for High School General Mathematics as Determined by an Appraisal of Present Content and Placement of Subject Matter. (Louisiana State U., 1958.) *Dis. Abst.* 19: 745-746; Oct. 1958. (b-3)

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Wallace, David Campbell. The Impact of Computer Mathematics on the Learning of High School Trigonometry and Physics. (U. Texas at Austin, 1968.) *Dis. Abst.* 29A: 3540; Apr. 1969. (d-6b; c-24, d-8)

Walter, Lina Rubright. Appreciation in Mathematics. (Columbia U., 1963.) *Dis. Abst.* 24: 2065-2066; Nov. 1963. (a-2)

Ware, James Gareth. An Enrichment Program for Superior Students in High School Plane Geometry. (George Peabody College for Teachers, 1962.) *Dis. Abst.* 23: 3917-3918; Apr. 1963. (e-3; c-23, e-4)

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Watson, Larry Wayne. The Relationship of the Mathematical Course Work of Teachers and the SAT-M Scores of Their Students. (Duke U., 1969.) *Dis. Abst.* 30A: 2892-2893; Jan. 1970. (ERIC Document No. ED 046 703) (t-2a; f-2c)

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Wells, David Wayne. The Relative Effectiveness of Teaching First Year Algebra by Television-Correspondence Study and Teaching First Year Algebra by Conventional Methods. (U. Nebraska Teachers College, 1959.) *Dis. Abst.* 20: 3137; Feb. 1960. (a-4; c-22, d-4)

Werner, Sister Marijane. An Application of Critical Path Analysis to the Design of a Systematically Articulated Curriculum in Science and Mathematics for Secondary Schools. (Boston College, 1968.) *Dis. Abst.* 29A: 4209-4210; June 1969. (b-4; a-5i, b-3)

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Whelan, James Francis. Correlation of the Professional and Subject Matter Training in the Preparation of Teachers of High School Mathematics. (Ohio State U., 1938.) (t-1b)

Whitaker, Mack L. A Study of Participants in Summer Mathematics Institutes Sponsored by the National Science Foundation. (Florida State U., 1961.) *Dis. Abst.* 22: 2712; Feb. 1962. (t-2b; d-9)

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Wiebe, Arthur John. The Comparative Effects of Three Methods of Utilizing Programmed Mathematics Materials with Low-Achievers. (Stanford U., 1966.) *Dis. Abst.* 27A: 1002-1003; Oct. 1966. (d-5; c-21, e-2a, g-6)

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Willcutt, Robert Ernest. Ability Grouping by Content Subject Areas in Junior High School Mathematics. (Indiana U., 1967.) Dis. Abst. 28A: 2152; Dec. 1967. (e-4)

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Willets, William Madeira. New Objectives for Ninth Grade Mathematics. (Temple U., 1944.) (a-5i; b-3, c-21, c-22)

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Wilson, Jack D. Trends in Elementary and Secondary School Mathematics, 1918-1948. (Stanford U., 1950.) (a-1)

Wilson, James William. Generality of Heuristics as an Instructional Variable. (Stanford U., 1967.) Dis. Abst. 28A: 2575; Jan. 1968. (a-4; a-5b)

Wilson, John Donald. An Analysis of the Plane Geometry Content of Geometry Textbooks Published in the United States Before 1900. (U. Pittsburgh, 1959.) Dis. Abst. 20: 1648; Nov. 1959. (d-1; a-1, c-23)

Winzenread, Marvin Russell. Consumable Materials: A Quasi-Programmed Procedure Experimentally Tested in the Inner-City Junior High School Mathematics Classroom. (Indiana U., 1969.) Dis. Abst. 30A: 4343; Apr. 1970. (d-5; d-1, e-7)

Wixson, Eldwin Atwell, Jr. The Effects of a Mathematical Approach to Teaching Two Topics in High School Biology on Student Achievement and Attitudes. (U. Michigan, 1969.) Dis. Abst. 31A: 1157; Sept. 1970. (d-8; b-3, c-30)

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Wolfe, Martin Sylvester. Effects of Expository Instruction in Mathematics on Students Accustomed to Discovery Methods. (U. Illinois, 1963.) Dis. Abst. 24: 206-207; July 1963. (a-4; c-22, d-5, d-9)

Wolfe, Richard Edgar. Strategies of Justification Used in the Classroom by Teachers of Secondary School Mathematics. (U. Illinois, 1969.) Dis. Abst. 30A: 1064-1065; Sept. 1969. (t-2d; a-4, c-21, c-22, c-23)

Wong, Ruth Eiko Murashige. Status and Direction of Geometry for Teachers. (U. Michigan, 1968.) Dis. Abst. 29A: 2597-2598; Feb. 1969. (t-1b; c-23)

Wood, Nolan Earl, Jr. The Effect of an In-Service Training Program in Verbal Interaction Analysis on Teacher Behavior in the Classroom. (U. Houston, 1968.) Dis. Abst. 29A: 3788-3789; May 1969. (t-2b; t-2c, t-2d)

Woodall, Parker Glenn. A Study of Pupils' Achievements and Attitudes in the School Mathematics Study Group and the Traditional Mathematics Programs of the Lewiston School District, 1960-1965. (U. Idaho, 1966.) Dis. Abst. 27B: 4040-4041; May 1967. (d-9; a-4, a-6)

Woodby, Lauren Gayle. A Synthesis and Evaluation of Subject-Matter Topics in Mathematics for General Education. (U. Michigan, 1952.) Dis. Abst. 12: 531; Issue No. 4, 1952. (b-4; c-26)

Woods, Dale. Topical Content for Certain Fifth-Year Mathematics Courses for Missouri Secondary School Mathematics Teachers. (Oklahoma State U., 1961.) Dis. Abst. 23: 549-550; Aug. 1962. (t-2b; b-3)

Wriggle, Lawrence Kay. The Amount and Nature of Teacher Help Necessary for Optimum Achievement Through Use of Programed Learning Devices. (Washington State U., 1964.) Dis. Abst. 25: 5802-5803; Apr. 1965. (d-5)

Wright, James Thomas Carr. The Function of Mathematics in a State Educational Program. (George Peabody College for Teachers, 1938.) (b-3)

Wright, Robert Earl. A Comparison of Student Achievement in Modern Mathematics and Traditional Mathematics in Relation to Ability Grouping. (Arizona State U., 1965.) Dis. Abst. 26: 3178; Dec. 1965. (a-4; e-4)

Wynn, Robert Sawtelle, Jr. A Study of the Relative Efficiency of Three Methods of Teaching Percentage in Grade Seven. (Colorado State College, 1965.) Dis. Abst. 26: 5313; Mar. 1966. (c-6)

Yasin, Said Taha. The Reform Movement in Secondary Mathematics--Its History and Present State. (Indiana U., 1961.) Dis. Abst. 22: 3084; Mar. 1962. (a-1; b-3)

Yasui, Roy Yoshio. An Analysis of Algebraic Achievement and Mathematical Attitude Between the Modern and Traditional Mathematics Programs in the Senior High School: A Longitudinal Study. (U. Oregon, 1967.) Dis. Abst. 28A: 4967-4968; June 1968. (a-4)

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Zahn, Karl George. The Optimum Ratio of Class Time to be Allotted to Developmental Activities and to Individual Practice in Teaching Arithmetic. (U. Colorado, 1965.) Dis. Abst. 26: 6459; May 1966. (b-6; a-4)

Zamboni, Floyd Frank. A Study of the Effect of Two Different Classroom Procedures Upon Student Achievement, Anxiety and Attitudes of Second Year High School Algebra II/Trigonometry Students. (Colorado State College, 1968.) Dis. Abst. 29B: 3004-3005; Feb. 1969. (e-5; a-6, c-22, c-24)

Zant, James Howard. The Teaching Plan for the Unit of Work in Junior High School Mathematics. (Teachers College, Columbia U., 1933.) (a-4)

Zelechoski, Robert J. The Learning of Signed Numbers in Grades Seven, Eight, and Nine. (Pennsylvania State U., 1960.) Dis. Abst. 21: 1861; Jan. 1961. (c-9)

Ziebarth, Raymond Allan. The Effect of Experimental Curricula on Mathematics Achievement in High School. (U. Minnesota, 1963.) *Dis. Abst.* 24: 4593; May 1964. (d-9)

Zoll, Edward Joseph. The Relative Merits of Teaching Plane Geometry with Varying Amounts of Applications. (New York U., 1957.) *Dis. Abst.* 18: 971-972; Mar. 1958. (c-23; a-2)

Zur, Mordehai. Implications of the Recent Mathematics Reform for Grades 7-9 in the United States for the Israeli Elementary and Secondary Schools. (Columbia U., 1966.) *Dis. Abst.* 28A: 4436; May 1968. (a-7)

APPENDIX C-1

FREQUENCY OF REPORTS BY JOURNAL SOURCE

American Education	1
American Educational Research Journal	5
American Journal of Mental Deficiency	8
American Mathematical Monthly	8
Arithmetic Teacher	40
AV Communication Review	3
Audiovisual Instruction	1
California Journal of Educational Research	10
Catholic Education Review	1
Chicago Schools Journal	2
Child Development	7
Clearing House	1
Contemporary Education	1
Education of the Visually Handicapped	1
Educational Administration and Supervision	7
Educational Method	4
Educational Outlook	1
Educational and Psychological Measurement	12
Educational Research Bulletin	4
Elementary School Journal	37
ERIC Documents	100
Exceptional Children	2
Graduate Research in Education and Related Disciplines	4
Harvard Educational Review	2
High Points	18
Indiana University School of Education Bulletin	4
Journal of Applied Psychology	9
Journal of Clinical Psychology	1
Journal of Educational Measurement	10
Journal of Educational Psychology	33
Journal of Educational Research	63
Journal of Experimental Child Psychology	1
Journal of Experimental Education	32
Journal of Experimental Psychology	2
Journal of Genetic Psychology	19
Journal for Research in Mathematics Education	3
Journal of Research Services	1
Journal of School Psychology	1
Journal of Social Psychology	2
Journal of Speech Disorders	1
Journal of Teacher Education	2
Mathematics Teacher	129
Peabody Journal of Education	6
Perceptual Motor Skills	1
Personnel and Guidance Journal	2
Pittsburgh Schools	2
Psychological Reports	12
Psychology in the Schools	5
School Board Journal	1
School and Community	1
School Executive	2
School Review	36
School Science and Mathematics	108
School and Society	5
Science Education	1
Supplementary Educational Monographs	1
Teachers College Record	1
Texas Outlook	1
Training School Bulletin	1
Wisconsin Journal of Education	1

APPENDIX C-2

FREQUENCY OF DISSERTATIONS BY UNIVERSITY AND YEAR

University	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970	Total
Alabama Polytechnic Institute						1				1
American University								1		1
Arizona State University								7		7
Auburn University								2	2	4
Boston College								1		1
Boston University School of Education						2	1		1	4
Brigham Young University							1	2		3
Carnegie-Mellon University								1		1
Catholic University of America			1			2	1	4		8
Claremont Graduate School and University Center								2		2
Colorado State College			1		1	1	3	11	3	20
Columbia University	9	4	5	2	14	3	7	16	3	63

APPENDIX C-2 (continued, p. 2)

University	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970	Total
Cornell University							1	5	1	7
Duke University									2	2
Florida State University							2	12	3	17
Fordham University	2		1	1			1	2		7
George Peabody College for Teachers	1	2	1	1	4	7	5	2	1	24
Harvard University	1			1	2					4
Howard University		1								1
Indiana University	1		1			6	7	13	4	32
Johns Hopkins University	1									1
Lehigh University								1	1	2
Louisiana State University						1	1			2
Michigan State University							1	3		4
New York University	1	3	3	1	3	4	9	9		33
North Texas State University							1	2	1	4
Northwestern University	1		1		1	2	1	2		8

APPENDIX C-2 (continued, p. 3)

University	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970	Total
Ohio State University		1		2		9	5	10	5	32
Oklahoma State University							5	8		13
Oregon State University								2		2
Pennsylvania State University		1		3	3	2	4	3		16
Princeton University							1	1		2
Purdue University							1	2	1	4
Rutgers University				1			1	9	2	13
Southern Illinois University								3		3
St. Louis University								1		1
Stanford University				2	1	1	2	9	1	16
State University of Iowa	3	1		1		5	5	7	2	24
State University of New York at Albany									1	1
State University of New York at Buffalo								1		1
Syracuse University						1		5	2	8

APPENDIX C-2 (continued, p. 4)

University	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970	Total
Temple University			2			1	2	3	6	14
Texas A & M University								1		1
Texas Technological College								1		1
University of Alabama							2	3		5
University of Arizona								2		2
University of Arkansas						1	1	2	1	5
University of Buffalo							1			1
University of California at Berkeley								5		5
University of Chicago			1		2					3
University of Colorado							2	3	1	6
University of Connecticut							1	3		4
University of Denver							1	1	1	3
University of Florida					1		2		4	7
University of Georgia								12	2	14
University of Houston						2	2	4		8

APPENDIX C-2 (continued, p. 5)

University	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970	Total
University of Idaho								2	1	3
University of Illinois					1	4	4	15	2	26
University of Kansas		1	2				2	3		8
University of Kentucky								1	1	2
University of Maryland							2	4	1	7
University of Miami								1		1
University of Michigan				1	3	1	5	13	6	29
University of Minnesota		1	1	1	1	4	10	10	3	31
University of Mississippi								4	1	5
University of Missouri	2		1			1	3	1		8
University of Nebraska (Teachers College)			1		1		3	9	2	16
University of New Mexico							1	2		3
University of North Carolina							1	2	1	4
University of North Dakota								1		1
University of Ohio	1									1

APPENDIX C-2 (continued, p. 6)

University	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970	Total
University of Oklahoma						2	2	6	1	11
University of Oregon						1	2	5		8
University of Pennsylvania							1			1
University of Pittsburgh			3			6	2	4	2	17
University of Rochester							1		2	3
University of South Carolina								2		2
University of South Dakota								1	1	2
University of Southern California	1				1	1	3	7	2	15
University of Southern Mississippi							1			1
University of Tennessee						1		1		2
University of Texas at Austin	1		2				2	6	3	14
University of Toledo								3		3
University of Toronto									1	1
University of Utah						1		1		2

APPENDIX C-2 (continued, p. 7)

University	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970	Total
University of Virginia		1				1	1	7	2	12
University of Wisconsin	2	2			1	5	6	10	2	28
Utah State University								2	1	3
Washington State University								2		2
Washington University						1				1
Wayne State University							1	5	1	7
Wayne University						1				1
(Case) Western Reserve University								5	1	6
Yale University		1		1		1				3
Yeshiva University							2			2
Subtotal by Year	27	19	27	18	40	82	135	334	88	770

APPENDIX D-1

FREQUENCY OF REPORTS BY YEAR

1930	19	1950	6
1931	14	1951	7
1932	35	1952	8
1933	16	1953	10
1934	19	1954	11
1935	23	1955	10
1936	19	1956	14
1937	23	1957	13
1938	10	1958	11
1939	13	1959	12
1940	8	1960	20
1941	18	1961	21
1942	6	1962	24
1943	14	1963	29
1944	12	1964	31
1945	7	1965	26
1946	10	1966	39
1947	9	1967	45
1948	7	1968	39
1949	20	1969	56
		1970	46
		Total	**780**

APPENDIX D-2

FREQUENCY OF DISSERTATIONS BY YEAR

1930	3	1950	11
1931	6	1951	7
1932	8	1952	14
1933	6	1953	1
1934	4	1954	7
1935	4	1955	16
1936	1	1956	13
1937	4	1957	16
1938	7	1958	19
1939	3	1959	18
1940	12	1960	22
1941	1	1961	20
1942	6	1962	33
1943	4	1963	27
1944	4	1964	33
1945	0	1965	44
1946	2	1966	71
1947	6	1967	61
1948	4	1968	68
1949	6	1969	90
		1970	88
		Total	770

APPENDIX E-1

FREQUENCY OF REPORTS BY MATHEMATICAL TOPIC AND TYPE OF STUDY

Type of Study (see p. 228 for code)	d	s	c	a	r	f	e	Total	Cross References	Sum*
Historical developments (a-1)	3	1						4	7	11
Nature, values, and uses of mathematics (a-2)		2						2	6	8
Organizational patterns (a-3)				4		2	3	9	5	14
Teaching approaches (a-4)		3		11		7	28	49	30	79
Drill and practice (a-5a)				1				1	8	9
Problem solving (a-5b)		5		1	5	3	9	23	15	38
Estimation (a-5c)							1	1	0	1
Mental computation (a-5d)						1	1	2	1	3
Homework and supervised study (a-5e)				5	1		5	11	2	13
Review (a-5f)								0	0	0
Checking (a-5g)								0	0	0
Writing and reading numerals (a-5h)		2						2	0	2
Specification of objectives (a-5i)							1	1	5	6
Attitude, self-concept, and climate (a-6)		20		1	3	2	2	28	29	57
International comparisons (a-7)	9	2		1		3		15	6	21
Subtotal	12	35	0	24	9	18	50	148	114	262

APPENDIX E-1 (continued, p. 2)

Type of Study	d	s	c	a	r	f	e	Total	Cross References	Sum*
Pre-first grade concepts (b-1)								0	1	1
Readiness (b-2)								0	1	1
Content organization and inclusion (b-3)	3	13		3		2		21	17	38
Quantitative understanding (b-4)		5			1			6	1	7
Grade placement (b-5)	1	4				2		7	7	14
Time allotment (b-6)				1		1	3	5	3	8
Subtotal	4	22	0	4	1	5	3	39	30	69
Counting (c-1)								0	0	0
Number properties and relations (c-2)		2	1				1	4	3	7
Whole numbers (c-3)		1						1	10	11
Addition (c-3a)								0	2	2
Subtraction (c-3b)		1				1		2	1	3
Multiplication (c-3c)								0	2	2
Division (c-3d)	1	4						5	3	8
Fractions (c-4)		2		1				3	3	6
Addition (c-4a)								0	0	0
Subtraction (c-4b)								0	0	0
Multiplication (c-4c)								0	0	0
Division (c-4d)								1	0	1

APPENDIX E-1 (continued, p. 3)

Type of Study	d	s	c	a	r	f	e	Total	Cross References	Sum*
Decimals (c-5)		2					1	3	3	6
Percentage (c-6)	1	1					2	4	0	4
Ratio and proportion (c-7)		2						2	0	2
Measurement (c-8)		2					2	4	11	15
Negative numbers (c-9)							1	1	3	4
Algebra in elementary school (c-10)								0	3	3
Geometry in elementary school (c-11)		1					3	4	1	5
Sets (c-12)		1						1	3	4
Logic and proofs (c-13)		1		2		1	2	6	5	11
The decimal numeration systems (c-14)		1						1	2	3
Other numeration systems (c-15)							1	1	5	6
Probability and statistics (c-16)				2		1	1	4	0	4
Functions; graphing (c-17)								0	4	4
Basic arithmetic procedures in secondary school (c-20)					1	1		2	7	9
General Mathematics course (c-21)								0	29	29
Algebra course (c-22)	1	1			1		1	4	126	130
Geometry course (c-23)	2	1		3	1	1	1	9	73	82
Trigonometry course (c-24)								0	4	4
Calculus course (c-25)				1				1	1	2
Other courses (c-26)	2							2	2	4

APPENDIX E-1 (continued, p. 4)

Type of Study	d	s	c	a	r	f	e	Total	Cross References	Sum*
Other topics (c-30)								0	1	1
Subtotal	7	24	1	9	3	5	16	65	307	372
Textbooks (d-1)	9			1			1	11	23	34
Workbooks, other printed materials (d-2)	1			1			2	4	4	8
Manipulative devices, games (d-3)		1		2			2	5	10	15
Audio-visual devices (d-4)		2		4	1		6	13	8	21
Programmed instruction (d-5)				13	1	1	22	37	30	67
Computer-aided instruction (d-6)		1						1	0	1
Tutorial (d-6a)				1				1	4	5
Non-tutorial (d-6b)		1		1				2	3	5
Readability and vocabulary (d-7)	8	2		4	5		8	27	8	35
Quantitative concepts in other curricular areas (d-8)	4	2		2	2	1	1	12	11	23
Developmental projects (d-9)				2		1	3	6	25	31
Subtotal	22	9	0	31	9	3	45	119	126	245
Diagnosis (e-1)				1				1	2	3
Error analysis (e-1a)		12		1	1		1	15	12	27
Diagnostic procedures (e-1b)			1	2			1	4	4	8

APPENDIX E-1 (continued, p. 5)

Type of Study	d	s	c	a	r	f	e	Total	Cross References	Sum*
Remediation (e-2)		1	1	20				22	15	37
Low achiever, underachiever (e-2a)			1	7		1	3	12	10	22
Slow learner (e-2b)			1				2	3	2	5
Mentally retarded (e-2c)		1			1	2	1	5	7	12
Tutoring (e-2d)							1	1	1	2
Enrichment (e-3)		4		3	1		1	9	11	20
Overachiever (e-3a)								0	3	3
Acceleration (e-3b)		2		5		4	4	15	2	17
Grouping procedures (e-4)				4	1	2	6	13	13	26
Physical, psychological, and/or social characteristics (e-5)		17			4	12	3	36	14	50
Sex differences (e-6)		3		1	2	5		11	14	25
Socioeconomic differences (e-7)		1		1		1		3	10	13
Subtotal	0	41	4	45	10	27	23	150	120	270
Testing (f-1)					2			2	4	6
Analysis and validation of tests (f-1a)	2	6		3	19	2	1	33	16	49
Status testing (f-1b)		12		2		3		17	14	31
Achievement evaluation (f-2)		10		1	8	11		30	34	64
Related to age (f-2a)					2		1	3	4	7

APPENDIX E-1 (continued, p. 6)

Type of Study	d	s	c	a	r	f	e	Total	Cross References	Sum*
Related to intelligence (f-2b)		3			6			9	22	31
Related to prediction (f-2c)		3			40	2		45	23	68
Effect of parental knowledge (f-3)								0	3	3
Effect of teacher background (f-4)		3		1	1	1	1	7	9	16
Subtotal	2	37	0	7	78	19	3	146	129	275
Transfer (g-1)		1					4	5	6	11
Retention (g-2)		1		2	1	2	1	7	7	14
Generalization (g-3)		1					1	2	4	6
Thought processes (g-4)		4		4	5	1	8	22	19	41
Motivation (g-5)		2		1	1	5	5	14	8	22
Reinforcement (g-6)		2						2	0	2
Knowledge of results (g-6a)							2	2	2	4
Other procedures (g-6b)				1			4	5	1	6
Piagetian concepts (g-7)								0	1	1
Conservation (g-7a)								0	0	0
Development (g-7a-1)								1	0	1
Training (g-7a-2)								0	0	0
Relation to achievement (g-7a-3)								0	0	0
Transitivity (g-7b)							2	2	0	2

APPENDIX E-1 (continued, p. 7)

Type of Study	d	s	c	a	r	f	e	Total	Cross References	Sum*
Piagetian concepts:										
Classification and seriation (g-7c)								0	0	0
Other (g-7d)		1					1	2	2	4
Subtotal	0	13	0	8	7	8	28	64	50	114
Pre-service (t-1)								0	0	0
Competency levels (t-1a)		2			1	1		4	5	9
Preparation procedures (t-1b)		9				1		10	3	13
Attitudes (t-1c)								0	0	0
Characteristics (t-1d)								0	2	2
In-service (t-2)		1						1	0	1
Competency levels (t-2a)		9						9	5	14
In-service procedures (t-2b)		4		2				6	7	13
Attitudes (t-2c)		6						6	3	9
Characteristics (t-2d)		12			1			13	10	23
Subtotal	0	43	0	2	2	2	0	49	35	84
TOTALS	47	224	5	130	119	87	168	780	911	1691

*Total of Primary and Cross-References

APPENDIX E-2

FREQUENCY OF DISSERTATIONS BY MATHEMATICAL TOPIC AND TYPE OF STUDY

Type of Study (see p. 228 for code)	d	s	c	a	r	f	e	un	Total	Cross References	Sum*
Historical developments (a-1)	17							8	25	24	49
Nature, values, and uses of mathematics (a-2)	2	2					1	2	7	9	16
Organizational patterns (a-3)		2		1		4	6		13	1	14
Teaching approaches (a-4)		1		1		6	43	6	57	23	80
Drill and practice (a-5a)							1		1	1	2
Problem solving (a-5b)		3			5	1	2	4	15	13	28
Estimation (a-5c)									0	0	0
Mental computation (a-5d)							1		1	0	1
Homework and supervised study (a-5e)							3		3	4	7
Review (a-5f)							1		1	0	1
Checking (a-5g)									0	0	0
Writing and reading numerals (a-5h)									0	0	0
Specification of objectives (a-5i)		1					1	1	3	5	8
Attitude, self-concept, and climate (a-6)		4		1	5	3	1		14	32	46
International comparisons (a-7)	11				2	1			14	8	22
Subtotal	30	13	0	3	12	15	60	21	154	120	274

APPENDIX E-2 (continued, p. 2)

Type of study	d	s	c	a	r	f	e	un	Total	Cross References	Sum*
Pre-first grade concepts (b-1)									0	0	0
Readiness (b-2)							1		1	0	1
Content organization and inclusion (b-3)	14	16		2	1	2	1	7	43	48	91
Quantitative understanding (b-4)	2	1		1					4	11	15
Grade placement (b-5)							1		1	4	5
Time allotment (b-6)							3		3	1	4
Subtotal	16	17	0	3	1	2	6	7	52	64	116
Counting (c-1)									0	0	0
Number properties and relations (c-2)				1					1	11	12
Whole numbers (c-3)					1				1	4	5
Addition (c-3a)									0	1	1
Subtraction (c-3b)									0	2	2
Multiplication (c-3c)									0	3	3
Division (c-3d)									0	1	1
Fractions (c-4)								1	1	1	2
Addition (c-4a)									0	0	0
Subtraction (c-4b)									0	0	0
Multiplication (c-4c)									0	0	0
Division (c-4d)									0	0	0

APPENDIX E-2 (continued, p. 3)

Type of Study	d	s	c	a	r	f	e	un	Total	Cross References	Sum*
Decimals (c-5)					1				1	1	2
Percentage (c-6)		1					3		4	1	5
Ratio and proportion (c-7)									0	2	2
Measurement (c-8)							4		4	7	11
Negative numbers (c-9)					1		1		2	4	6
Algebra in elementary school (c-10)									0	0	0
Geometry in elementary school (c-11)	1	2					2		5	3	8
Sets (c-12)							1		1	2	3
Logic and proofs (c-13)	2	1		2	1	3	4	1	14	15	29
The decimal numeration systems (c-14)									0	2	2
Other numeration systems (c-15)	1						1		2	4	6
Probability and statistics (c-16)				1	1	2	3	2	9	3	12
Functions; graphing (c-17)	3	1		2			2	1	9	6	15
Basic arithmetic procedures in secondary school (c-20)						2			2	7	9
General Mathematics course (c-21)								1	1	18	19
Algebra course (c-22)	2	2		3		2	2	6	17	92	109
Geometry course (c-23)	7			2			6	12	27	70	97
Trigonometry course (c-24)	2								2	3	5
Calculus course (c-25)				1				1	2	6	8
Other courses (c-26)	1	2		2		1			6	8	14

APPENDIX E-2 (continued, p. 4)

Type of Study	d	s	c	a	r	f	e	un	Total	Cross References	Sum*
Other topics (c-30)	2			3			2		7	20	27
Subtotal	21	9	0	17	5	10	31	25	118	297	415
Textbooks (d-1)	13						2		15	27	42
Workbooks, other printed materials (d-2)							1	1	2	0	2
Manipulative devices, games (d-3)		1					6	2	9	10	19
Audio-visual devices (d-4)	1	1		1			6	3	12	3	15
Programmed instruction (d-5)	1	1		3	1		23		29	33	62
Computer-aided instruction (d-6)									0	0	0
Tutorial (d-6a)				1			1		2	3	5
Non-tutorial (d-6b)							4		4	1	5
Readability and vocabulary (d-7)		2		1			1	4	8	0	8
Quantitative concepts in other curricular areas (d-8)	2	2		2	6	2	5	3	22	5	27
Developmental projects (d-9)	5					3	2		10	49	59
Subtotal	22	7	0	8	7	5	51	13	113	131	244
Diagnosis (e-1)								1	1	3	4
Error analysis (e-1a)		1				1		2	4	3	7
Diagnostic procedures (e-1b)							2	2	4	2	6

APPENDIX E-2 (continued, p. 5)

Type of Study	d	s	c	a	r	f	e	un	Total	Cross References	Sum*
Remediation (e-2)				1		1	1		3	5	8
Low achiever, underachiever (e-2a)			1		2	1	1	1	6	9	15
Slow learner (e-2b)							3	1	4	6	10
Mentally retarded (e-2c)		1			1		2		4	2	6
Tutoring (e-2d)				1			3		4	0	4
Enrichment (e-3)		3		2			3	1	9	5	14
Overachiever (e-3a)									0	2	2
Acceleration (e-3b)						3	2		5	5	10
Grouping procedures (e-4)		1		3		2	7	1	14	11	25
Physical, psychological, and/or social characteristics (e-5)		1			7	3	4		15	5	20
Sex differences (e-6)		1							1	10	11
Socioeconomic differences (e-7)		1				3	1		5	9	14
Subtotal	0	9	1	7	10	14	29	9	79	77	156
Testing (f-1)								1	1	2	3
Analysis and validation of tests (f-1a)	4	3			12		4		23	12	35
Status testing (f-1b)		5				3			8	5	13
Achievement evaluation (f-2)		2			3	2		11	18	6	24
Related to age (f-2a)					1				1	3	4

APPENDIX E-2 (Continued, p. 6)

Type of Study	d	s	c	a	r	f	e	un	Total	Cross References	Sum*
Related to intelligence (f-2b)					2	1			3	12	15
Related to prediction (f-2c)					18	1		4	23	15	38
Effect of parental knowledge (f-3)					1	1	1		3	2	5
Effect of teacher background (f-4)		1		2	3	5	2	1	14	6	20
Subtotal	4	11	0	2	40	13	7	17	94	63	157
Transfer (g-1)									0	0	0
Retention (g-2)				1	1		1	1	4	2	6
Generalization (g-3)		1					1	1	3	1	4
Thought processes (g-4)	1	3		1	3		7	4	19	24	43
Motivation (g-5)		2				1	4	3	10	0	10
Reinforcement (g-6)								1	1	2	3
Knowledge of results (g-6a)							2		2	2	4
Other procedures (g-6b)									0	2	2
Piagetian concepts: Conservation (g-7a)					1				1	1	2
Development (g-7a-1)									0	0	0
Training (g-7a-2)							1		1	0	1
Relation to achievement (g-7a-3)									0	0	0
Transitivity (g-7b)									0	0	0

APPENDIX E-2 (continued, p. 7)

Type of Study	d	s	c	a	r	f	e	un	Total	Cross References	Sum*
Piagetian concepts:											
Classification and seriation (g-7c)									0	1	1
Other (g-7d)		3				2			5	3	8
Subtotal	1	9	0	2	5	3	16	10	46	38	84
Pre-service (t-1)		1							1	0	1
Competency levels (t-1a)		2				1			3	4	7
Preparation procedures (t-1b)	9	10		1	3			5	28	7	35
Attitudes (t-1c)		1							1	0	1
Characteristics (t-1d)		2	1						3	1	4
In-service (t-2)	1								1	2	3
Competency levels (t-2a)		7			2			3	12	5	17
In-service procedures (t-2b)	4	19	1	1		2	2		29	7	36
Attitudes (t-2c)		2				1	1	1	5	4	9
Characteristics (t-2d)	1	28			2				31	9	40
Subtotal	15	72	2	2	7	4	3	9	114	39	153
TOTALS	109	147	3	44	87	66	203	111	770	829	1599

*Total of Primary and Cross-References

ADDENDA

CATEGORIES AND CODING FOR TYPE OF STUDY

d	Descriptive:	research in which the researcher reports on records which may have been kept by someone else; includes reviews, historical studies, and textbook analyses or comparisons
s	Survey:	research which attempts to find characteristics of a population by asking a sample through the use of a questionnaire or interview; includes also the status study, in which a group is investigated as it is to ascertain pertinent characteristics (measures assigned variable only)
c	Case study:	research in which the researcher describes in depth what is happening to one designated unit, usually one child
a	Action research:	research which uses nominal controls; generally teacher or school originated; procedures of actual practice may be described
r	Correlational:	research which studies relationships between or among two or more variables; uses correlational statistic primarily
f	Ex post facto:	research in which the independent variable or variables were manipulated in the past; the researcher starts with the observation of a dependent variable or variables. He then studies the independent variables in retrospect for their possible effects on the dependent variables. (He may examine interrelationships of two or more assigned variables or two or more levels of one assigned variable)
e	Experimental:	research in which the independent variable or variables are manipulated by the researcher to quantitatively measure their effect on some dependent variable or variables, to test a logically derived hypothesis

APPENDIX F

LIST OF QUESTIONS

Page

1. PLANNING FOR INSTRUCTION

How do class organization patterns affect achievement? 5
What is the role of inductive and deductive strategies in the teaching-learning process? 6
How should time be allocated in mathematics instruction? 10
How effective is the specification of objectives? 11
How effective is homework? 12
Have there been attempts to analyze the historical development of mathematics in the secondary school curriculum? 13
What is the evidence on how well students achieve today compared with "the good old days"? 15
To what extent has modern mathematics been incorporated into the curriculum? 16
Is there research which identifies the outcomes of "modern" and "traditional" instruction? 16
To what extent are various courses offered in schools? 18
What new topics have been studied? 18
How effective are the materials from various major curriculum development projects? 19
What test development strategies have been found to be helpful? 21

2. ATTITUDES AND RELATED FACTORS

Do secondary school students like mathematics? 23
Does a more favorable attitude lead to higher achievement? 24
What is the relationship of teachers' attitudes to students' attitudes and achievement? 25
What is the relationship of self-concept in mathematics to achievement? 25
Does anxiety affect mathematical achievement? 26

3. CONTENT: WHAT, WHEN AND HOW

What serves as the best predictor of achievement for algebra, geometry, and other mathematics courses? 27
What has been ascertained about teaching the general mathematics course? 30
What has been ascertained about teaching algebra? 31
What has been ascertained about teaching geometry? 31
How should operations with whole numbers and with rational numbers be taught? 33

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How should ideas about percentage be taught? 33
How should work with integers be taught? 34
What is the role of logic in the secondary school curriculum? 34
Is the teaching of non-decimal bases effective? 35
What can students be taught about probability and statistics? 36
What other topics have been studied? 37
What factors are related to problem-solving ability? 38
What tests of Piaget's theory have been made with secondary school students? 40

4. INDIVIDUALIZING INSTRUCTION

Is grouping an effective way of providing for individual differences? 43
What is mathematical ability? 45
What mathematical errors are most commonly made by secondary school students? 45
What types of programs and materials are effective for slower learners and underachievers? 46
What types of programs and materials are effective for faster learners? 47
What personality factors have been found to be associated with mathematical achievement? 48
Do boys and girls achieve differently? 49
What is the effect on achievement of factors such as socioeconomic level (SES)? 50

5. INSTRUCTIONAL MATERIALS AND MEDIA

What are some characteristics of mathematics textbooks? 51
What is the effect of televised instruction? 52
How helpful is the use of other materials? 52
What is known about the effect of programmed instruction? 53
Does the use of desk calculators affect achievement? 58
What is the role of computers in the instructional process? 58

6. TEACHER EDUCATION

What is effective in pre-service education? 61
What in-service education procedures are effective? 62
What strategies and behaviors have teachers used? 63
How do teacher background and teacher behaviors affect students' achievement? 64